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Making the Sahara Desert Green
Sustainable transport of bottom lake sediments via pipelines to produce new agriculture land from desert

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Abstract

In a world which will be home to 9 billion people by the middle of this century, it will undoubtedly be a substantial challenge for humanity to produce enough food and other vital resources. Today there are tens of millions of hungry living in Africa. These people are missing not just food and potable water but also tap water, sewage, electricity, jobs and other living amenities.

This research focused on addressing these issues. One of the main problems identified for the mid-21st century will be the availability of fresh water. Currently, appx. 20% of the world's fresh water is stored in manmade reservoirs. However, these reservoirs sediment over time. This “sediment phenomena” adversely affects the water volume in reservoirs and their sustainable maintenance, potentially jeopardizing the fresh water supply. To answer the “sediment phenomena”, this dissertation developed a whole new approach to a no less devastating problem: the increasing desertification and land degradation. In arid regions, sediments are mostly composed of alluvial soil, decomposing organic matter and sands, making them indeed a perfect soil amendment.

This dissertation developed a patented “methodology for desert greening” that utilises the bottom lake sediments to preserve existing fresh water reservoirs. Sediments are transported away from the bottom of the reservoirs in order to use them as a soil kick-starter for surrounding dry areas. This approach does not only solve the sedimentation issues, but also the problem of food supply and unemployment, since a completely new ecosystem is developing around now fertile grounds, where there was only desolate land before.

The research was focused on Egypt and transforming the ecosystem in the New Valley parallel to the Nile Valley using Aswan High Dam Reservoir sediments, one of the largest man-made reservoirs. The research results show that the methodology can be applied on all continents and in the most diverse climate zones, being useful in moderate climate zones for the maintenance of dams, reservoirs and river basin control. Egypt was predestined for the research region, as one of the most populous countries in Africa and the Middle East.

The current population in Egypt is hovering around 100 million people, most of whom live on the banks of the River Nile. International organisations estimate Egypt's population will increase to 113 million by 2050. Other estimates from local media approach 200 million people. As most of the country’s landmass is desert (with less than 4% being agricultural land) and coupled with increasing mass migration towards the cities along the Nile Valley - which, in turn, comes at the expense of arable land – is underlining the urgency and importance of finding new solutions to deal with the overpopulated Nile Valley. The Aswan High Dam retains the alluvium that has served Egypt as a natural fertiliser for millennias while leading to the "sediment phenomenon" within the dam itself. At the same time, Egypt is one of the largest users of fertilisers among developing countries. With

high levels of poverty, especially in terms of food and arable land, there would be significant benefits if the ‘sediment phenomenon’ could be used, as Egypt is in dire need of new arable land.

This dissertation offers a scientific and practical solution for this.

Part of this approach is also the right selection and combination of native and naturalised plants, which on the one hand are able to cope with adversities of the environment and on the other hand create a sustainable added value for the ecosystem as a whole. Choosing the right plants is important both from the perspective of rapid implementation as well as the perspective of job creation and retention in the region.

Moringa Stenopetala and Moringa Oleifera are at the centre of the research results on the correct planting. The latter is listed as one of the key plants of the 21st century, by the Food and Agricultural Organisation (FAO) of the United Nations (UN), to combat undernutrition and malnutrition in developing countries. With a growth of 12 meters per year Moringa is one of the fastest growing trees/shrubs in the world. All parts of the Moringa tree - the bark, leaves, seeds, pods, fruits, tubers, flowers and root - are edible. The University of Lausanne, Switzerland is currently researching the ability of Moringa seeds to purify water. Preliminary results show that Moringa seeds can provide water quality which exceeds that of commercially treated one. Moringa has also been used successfully to produce biofuel.

This research developed a sustainable approach to address the challenges humankind will face in this half of our century: food shortages, the decline of fertile land, water scarcity, unemployment, and an increasingly fragile ecosystem of our habitats.

Kurzfassung

In einer Welt, die bis zur Mitte dieses Jahrhunderts 9 Milliarden Menschen ihr Zuhause nennen, wird es zweifelsohne eine Herausforderung sein, ausreichend lebensnotwendige Ressourcen wie Nahrungsmittel und Wasser sicherzustellen. Bereits heute leiden Millionen Menschen in Afrika täglich Hunger. Neben mangelnden Zugang zu Trinkwasser und ausreichend Nahrung, sind diese Regionen auch ohne fließend Wasser, Abwassersystemen, Elektrizität, Arbeitsplätze oder sonstige Annehmlichkeiten die anderswo als selbstverständlich empfunden werden.

Diese wissenschaftliche Arbeit ist diesen Herausforderungen gewidmet und konzentriert sich dabei auf die Frischwasser- und Nahrungsmittelversorgung. Eine der größten Herausforderungen des 21. Jahrhunderts wird die Versorgung mit Frischwasser sein. Aktuell werden etwa 20% des weltweiten Frischwassers in künstlichen Stauseen gespeichert. Diese Stauseen sedimentieren jedoch im Laufe der Zeit, was das Frischwasservolumen negativ beeinflusst und die Frischwasserversorgung gegebenenfalls potentiell gefährdet.

Die wissenschaftliche Erforschung von Lösungsansätzen zu dieser Gefahr hat auch einen völlig neuen Lösungsansatz zu einem nicht weniger verheerenden Problem erzeugt: die zunehmende Wüstenbildung und Landverödung. In den betroffenen ariden Gebieten bestehen die Sedimente häufig aus Schlamm, organischen Stoffen und Sand. Aus perfektem Dünger also.

Im Zuge dieser Dissertation wurde auf ihren Erkenntnissen basierend eine patentierte „Methodologie zur Begrünung von Wüstenlandschaften“ entwickelt, mit der diese Sedimente vom Grund der Stauseen im Sinne der Frischwasser-Erhaltung abtransportiert werden, um diese als Nährboden zur Begrünung umliegender Trockengebiete zu verwenden. Auf diese Weise wird nicht nur das Problem der Sedimentierung gelöst, sondern auch das Problem der Nahrungsmittelversorgung und Arbeitslosigkeit, da sich um das vormalige Trockengebiet nun ein völlig neues Ökosystem rund um das nunmehr fruchtbare Gebiet entwickelt.

Die Forschungen konzentrieren sich auf die Begrünung des New Valleys parallel zum Niltal mit Sedimenten des Aswan High Dam Stausees in Ägypten, einer der größten von Menschenhand geschaffenen Stauseen. Das Forschungsergebnis zeigt, dass die Methodologie auf allen Kontinenten und in den verschiedensten Klimazonen Anwendung finden kann und auch in moderatem Klimazonen zur Aufrechterhaltung der Dämme, Stauseen und Stromgebiete sinn- und wertvoll ist. Ägypten ist als eines der bevölkerungsreichsten Länder Afrikas und des Mittleren Osten als Forschungsregion prädestiniert.

Aktuell bewegt sich die Bevölkerungszahl in Ägypten um 100 Millionen Menschen, die zum größten Teil an den Ufern des Nils leben. Internationale Organisationen schätzen, dass sich die Bevölkerungszahl in Ägypten bis 2050 auf 113 Millionen erhöht. Andere Schätzungen lokaler Einrichtungen gehen sogar von 220 Millionen Menschen aus. Die Tatsache, dass das Land mit weniger als 4 % landwirtschaftlich nutzbarer Fläche

größtenteils aus Wüste besteht und der Bevölkerungsanstieg somit auch mit einer stetig steigenden Migration in jene Städte einhergeht, die entlang des Niltals liegen – was wiederrum auf Kosten der landwirtschaftlichen Nutzflächen geht – unterstreicht die Dringlichkeit und Wichtigkeit neue Lösungsansätze zu dieser Herausforderung zu finden.

Der Aswan High Dam hält die Schwemmstoffe zurück, die Ägypten jahrtausendelang als natürliche Dünger dienten, während sie beim Damm selbst zu dem „Sediment Phänomen“ führen. Gleichzeitig ist Ägypten der größten Abnehmer von künstlichen Düngemitteln aller Entwicklungsländern.

Ein Teufelskreis, der durchbrochen werden muss, um der steigenden Armut, Nahrungsknappheit, Wassermangel und weiteren Wüstenbildung Einhalt zu gebieten.

Diese Dissertation bietet einen so wissenschaftlichen wie praktikablen Lösungsansatz hierfür.

Teil dieses Lösungsansatzes ist auch die richtige Auswahl und Kombination von heimischen und nicht-heimischen Pflanzen, die einerseits den Widrigkeiten des Umfeldes gewachsen sind und andererseits einen nachhaltigten Mehrwert für das Ökosystem als Ganzes stiften. Aus der Perspektive der raschen Implementierung ebenso wie aus der Perspektive der Arbeitsplatzschaffung und -Erhaltung.

Im Zentrum der Forschungsergebnisse zur richtigen Bepflanzung stehen hierbei Moringa Stenopetala and Moringa Oleifera. Letztere wird von der Food and Agricultural Organisation (FAO) der United Nations (UN) als eine der Schlüsselpflanzen des 21. Jahrhundert geführt, um die Unter- und Fehlernährung in Entwicklungsländern zu bekämpfen. Mit einem Wachstum von 12 Metern pro Jahr gehört Moringa zu den am schnellsten wachsenden Bäumen der Welt. Alle Teile des Moringa Baumes – die Rinde, Blätter, Samen, Hülsen, Früchte, Knollen, Blüten und Wurzel – sind essbar. Die Universität Lausanne erforscht aktuell in der Schweiz die Fähigkeit der Moringa Samen, Wasser zu reinigen. Erste Ergebnisse zeigen, dass

mithilfe der Moringa Samen eine Wasserqualität erreicht werden kann, welche die des für den Handel abgefüllten Wassers übertrifft. Moringa wurde auch erfolgreich zur Herstellung von Biokraftstoff verwendet.

Mit der vorliegenden Dissertation wurde ein nachhaltiger Lösungsansatz entwickelt, um den künftigen Herausforderungen gewachsen zu sein, denen sich die Menschheit noch in dieser Hälfte unseres Jahrhunderts stellen muss: Nahrungsmittelknappheit, der Rückgang fruchtbaren Landes, Wasserknappheit, Arbeits- und Einkommenslosigkeit, und ein immer fragiler werdendes Ökosystem unseres Lebensraumes.

Citation and Contact

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Table of Contents

Contents

List of Figures

Literature Review

> *"Throughout history, agricultural development was always preceded by technological innovation and then followed by economic progress, which led to further technological progress and so on in a big spiral pattern, that grew bigger and bigger with each loop, until the present day. Today when growing bigger is out of the question in so many fields of life, especially for agriculture in the sense of acquiring new land at the expense of a forest or any other bio reserve we have to find new ways of producing twice the amount of product on the same piece of land. We have reached the final frontier. "Sustained growth", "sustainability", and "endurance" are just some of the words that have become part of our everyday vocabulary, not just out of the need to tame Mother Nature, but more pointedly the voracious economic growth that threatens to wipe us out of existence in the very near future. As the principles of sustainability that we have learned through time propose, the Earth has finite resources. It is not capable of matching our own economic and technological progress, let alone absorbing the agriculture which is overrunning countless habitats where forests were providing us with the oxygen in earlier millennia. We have learned what needs to be done to halt and prevent this global destruction. This work focuses on the aspects of helping the planet and preserving the natural resources with reflection on what has been done and what there is to be done to help this planet overcome the environmental crisis we have created."*
>
> *Vesela Tanaskovic*

If we look into our history and prehistory as race and try to mark the moments in time when a significant event of technological progress important to evolution has occurred, we can look at it like a line with dots.

To see these great events on a timeline, if we would look far enough back in time, we would see a dot, then lot of empty, empty, empty spaces, then a dot again, and so on, until we come closer to our own times. The dots slowly become closer, closer and closer until we reach today. And in the past century we would see a full thick line made up of all the incredible dots marking what humanity has invented.

Looking at this line, we can for example start by estimating when people started lighting fires, the genius of that time, and that this was a momentous innovation at the time. This made way for so many new inventions, it could be considered to be the first dot. But this timeline need not be a singular line, every little bit of technological progress allowed us to advance a little further in every other aspect, to have a bit more abundance and free time (as in case of fire we basically got an external stomach that, for instance, cut our chewing time in half; this added a little time to spend getting more food, having more free time) and slowly, slowly, slowly, our population grew.

In this way we can correlate interdependent lines throughout history: the agricultural development line, which was always preceded by a line of technological progress, and then followed by a population curve, which then led to further technological progress and so on in an escalating pattern, that grew bigger and bigger with each loop in a kind of spiral until the present day.

The Food and Agriculture Organisation of the United Nations, perhaps shows this best in one of their promo videos for their new program "Save and Grow" (1).

Agriculture growth is still the biggest contributor to deforestation worldwide. “In tropical and subtropical countries, large-scale commercial agriculture and subsistence agriculture accounted for 73 % of deforestation, with significant regional variations. For example, commercial agriculture accounted for almost 70 % of deforestation in Latin America but for only one-third in Africa, where small-scale agriculture is a more significant driver.” (2) We can note that technological progress is lacking, based on the previous curves or that it is not evenly distributed and available, which is the case today. Due to this obvious co-dependency, and because until now agriculture was always expanding at the expense of virgin forests, IPCC (the Intergovernmental Panel on Climate Change) addresses agriculture and forestry as one entity: AFOLU (agriculture, forestry, and other land use), counting them as 24 % of total anthropogenic greenhouse gas (GHG) emissions (gigatonne of CO2-equivalent per year, GtCO2-eq/yr) worldwide).

Figure 1 presents this by economic sector.

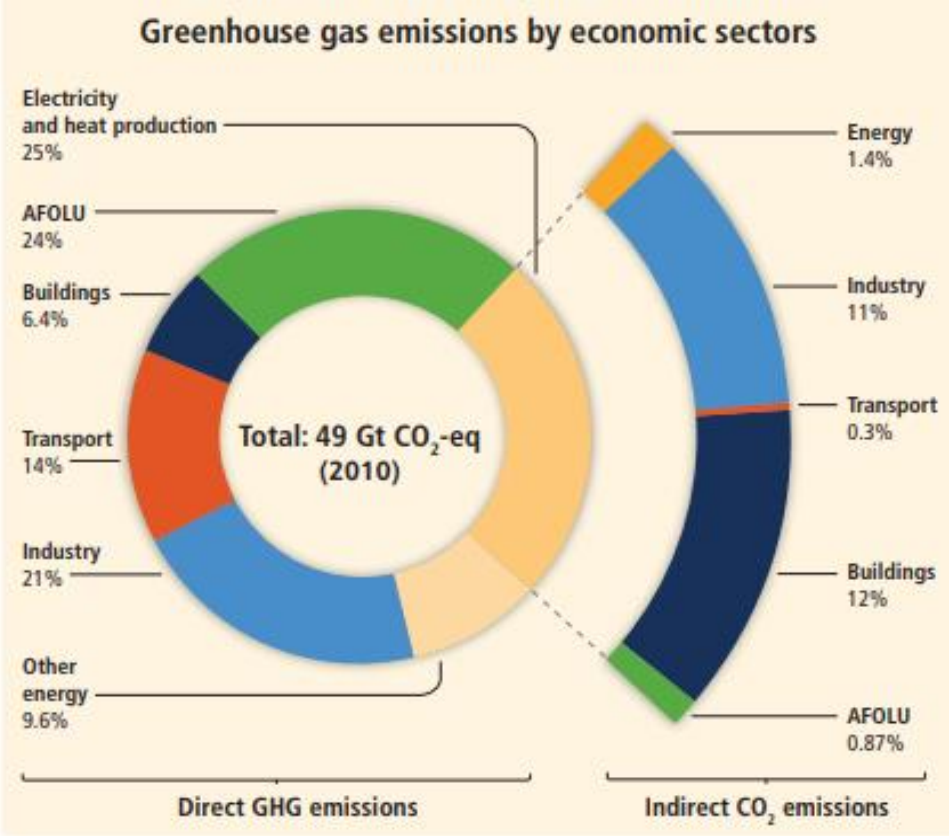

Figure 1. Total anthropogenic greenhouse gas (GHG) emissions (gigatonne of CO2-equivalent per year, GtCO2-eq/yr) (3)

As population is expected to reach its peak by 2050 (1), and to stabilize or decline afterwards according to the UN, this would mean that if we accept the historical developments, agricultural expansion will have to follow this curve. Knowing that agriculture is one of the main contributors to climate change, we need the technology to speed up and hasten this year of attainment more than ever.

Climate change exists beyond doubt.[1] It was created by these same three curves: agriculture, technology and population growth, and we need to put the end to the spiral. But, how and when will we be able to do this by the mid-century when the highest population peek is expected? This is still a big unknown and will certainly determine the future of condition of humanity as a whole.

Today when growing bigger is out of the question for so many sectors, especially agriculture, expansion on account of acquiring new land at the expense of forests or any other bio reserve is basically unimaginable. Twenty-first Century agriculture needs to develop the main sources of carbon emission into the main sources of carbon sinking, and this can only be achieved if the rate of technological progress exceeds our expectations. The thresholds that we are crossing, such as biosphere integrity (genetic diversity), biogeochemical flows (nitrogen cycles), climate change, land systems change, are rising at an alarming rate. And there is hardly a better way to emphasize the crisis we are in today than through the work of the Stockholm Resilience Centre, Planetary Boundaries visualization (Figure 2), as well as the full peer reviewed articles published by the centre on this subject, which analyses in depth each of the segments of the Planetary Boundaries comprehensive view of our planet's current state of affairs.

[1] There are different views on the definitions of global warming and climate change, most commonly accepted ones are given by UN and IPCC. Terms are sometimes used interchangeably, however in this thesis I will be using the term Climate Change, because I see it more appropriate. It engulfs a bigger change that is upon us, starting from desertification, flash floods and storms, to biodiversity loss; and of course, increase of greenhouse gases and temperature rise, which is undoubtedly global warming of the Earth"s surface. This phrasing by no means undermines the urgency and importance of acting now, on reversing the global warming and halting it to max 2C.

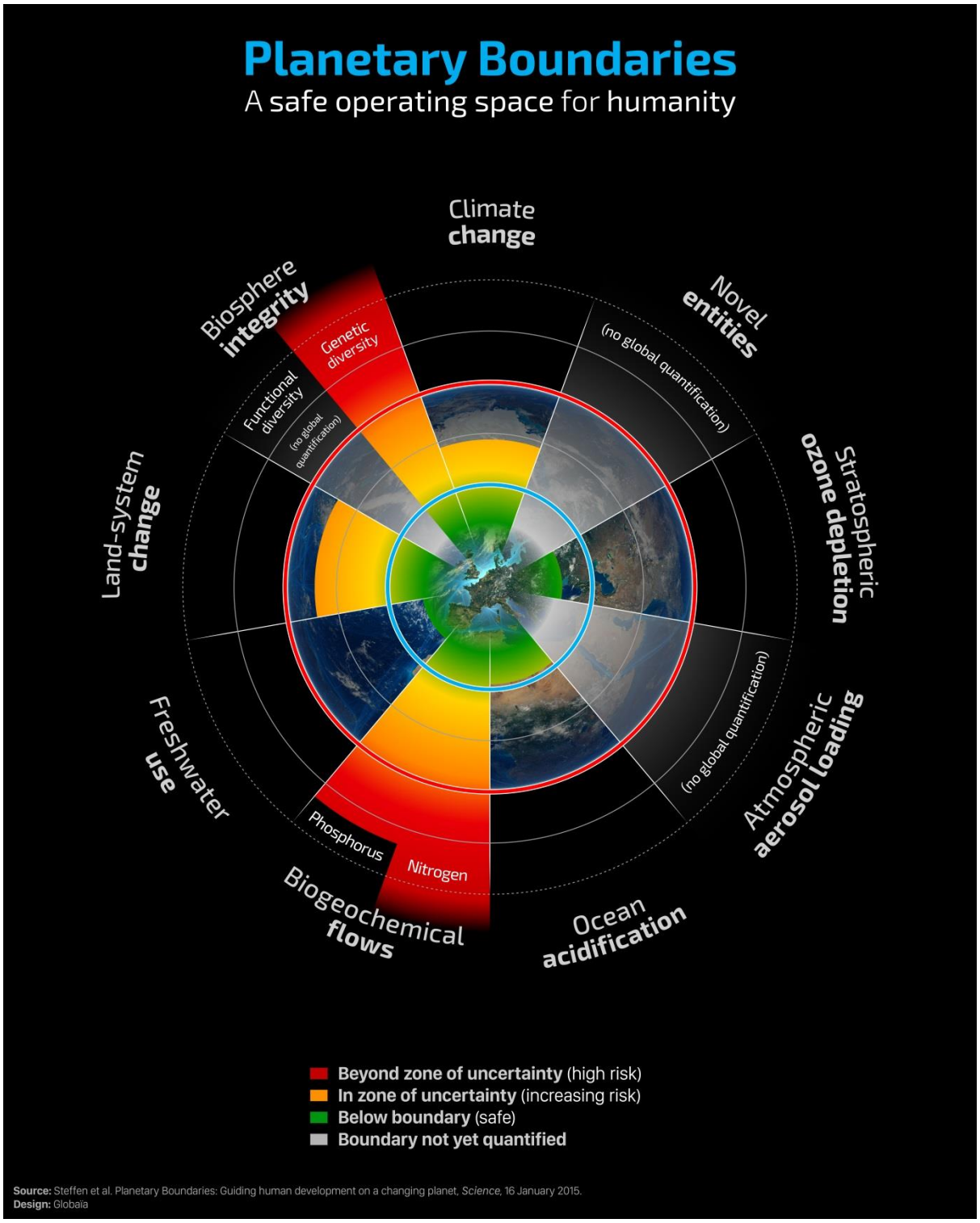

Figure 2. Planetary Boundaries (4)

This gives us a clear picture that pumping more artificial fertilisers into our soils will not contribute to anything but a bigger problem in our marine ecosystems to say the least. The same goes with genetic diversity and clear-cutting virgin forest to make way for agriculture and urbanisation. It is clear that we have to find new ways of producing double the amount of food on the same piece of land with half of the fresh water available. We have reached the final frontier on so many aspects in our environment. “Sustained growth”, “sustainability” and “endurance” are just some of the words that have come into our everyday vocabulary, not just out of the pure need to control the climate, but the voracious economic growth that threatens to wipe us all out of existence in the very near future if we continue with the current scenario of business as

usual. As the principles of sustainability propose and from what we have learned through time, Earth has a finite amount or resources, it is not capable of growing or following our exponential economic and technological progress, let alone the agricultural overtaking of countless habitats and cutting down forests that were proving us with shelter, food, and oxygen for millennia.

"Either way, we face an immediate and profound collective challenge to transform the current exponential increase in CO2 emissions (~2 % yr-1 over the past 25 years and >3 % yr-1 over the past decade) into a comparable or greater rate of decrease in CO2 emissions. This transition must start soon and be completed within decades, if Climate Change is to be restricted to less than 2°C above pre-industrial levels. Already it demands rates of technological and economic change that may simply be unachievable." (5) The same author goes on to conclude that the highest potential of reversing the climate change and CO2 emissions is seen in land based approaches such as afforestation, reforestation, and forestation, which will be fully explored further on in this thesis. "Current assessments suggest that land-based methods of CDR either via biological (photosynthesis) or physical and chemical means have greater potential than ocean-based methods." (5)

For these land-based CDR approaches the availably of the fresh water resources is of great importance, so is the ability to accurately predict weather patterns and what the climate change will bring. "…GCM projections of global precipitation for the twenty-first century broadly indicate a 'rich get richer' pattern in which regions of moisture convergence (or divergence) are expected to experience increased (or decreased) precipitation. There are no published studies applying a large ensemble of GCMs and greenhouse-gas emissions scenarios to generate recharge projections at the global scale." (6) Meaning that the semi-arid and arid regions are expected to have even smaller annual participation rates, which will not only hinder the agricultural development of one of the fastest growing regions on the planet, the MENA region, but also further impede the recovery of the desert ecosystems and contribute to greater losses in desert ecosystems which, due to their fragility, are one of the most endangered eco systems in the face of climate change.

We are yet to learn what needs to be done to halt and prevent the global destruction of commons, or to halt the Holocene–Anthropocene on-going extinction event. This thesis focuses on aspects of helping the planet from a multidisciplinary approach. It looks into different engineering branches and agricultural approaches that when combined would allow us to use existing abandoned and neglected lands. This can be done with little to no fresh water and enable productive agricultural harvests. The ultimate aim involves turning agriculture into the next carbon sink globally, and preserving the water storage ability of the existing engineering structures in place, to cope with the stress expected in the next decades of climate change.

Water stress causes and solutions in dry regions overview

How much water do we need?

World population passed 7 billion in October of 2011. (7) "Although the annual increase probably peaked at about 87 million around 1990, the high proportion of young people in most developing countries means that global population will continue to increase significantly well into this century. Recent projections suggest a peak of between 7.3 billion and 10.7 billion around 2050 before total population begins to stabilize or fall. Predictions cannot be precise because other dimensions of development such as access to health, education, income, birth control and other services influence the pace of

population growth." (8) What does this mean for our water security? If we look at the selected water stressed countries (Figure 3), we already see there are not only arid countries that are on this list but also countries like Germany and Poland, two of the central to northern European countries, considered abundant in fresh water resources up until quite recently. Figure 4 presents a map of the global situation.

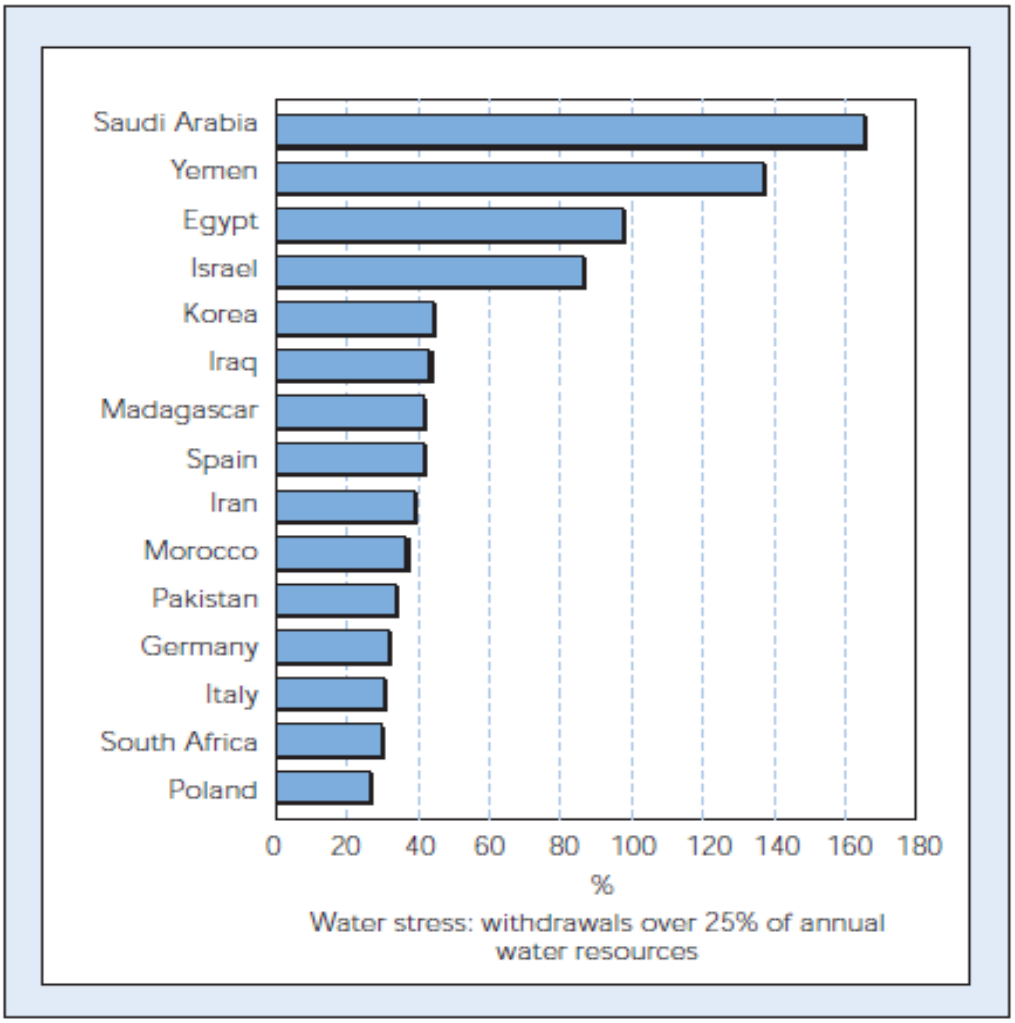

Figure 3. Water Stressed Countries. (8)

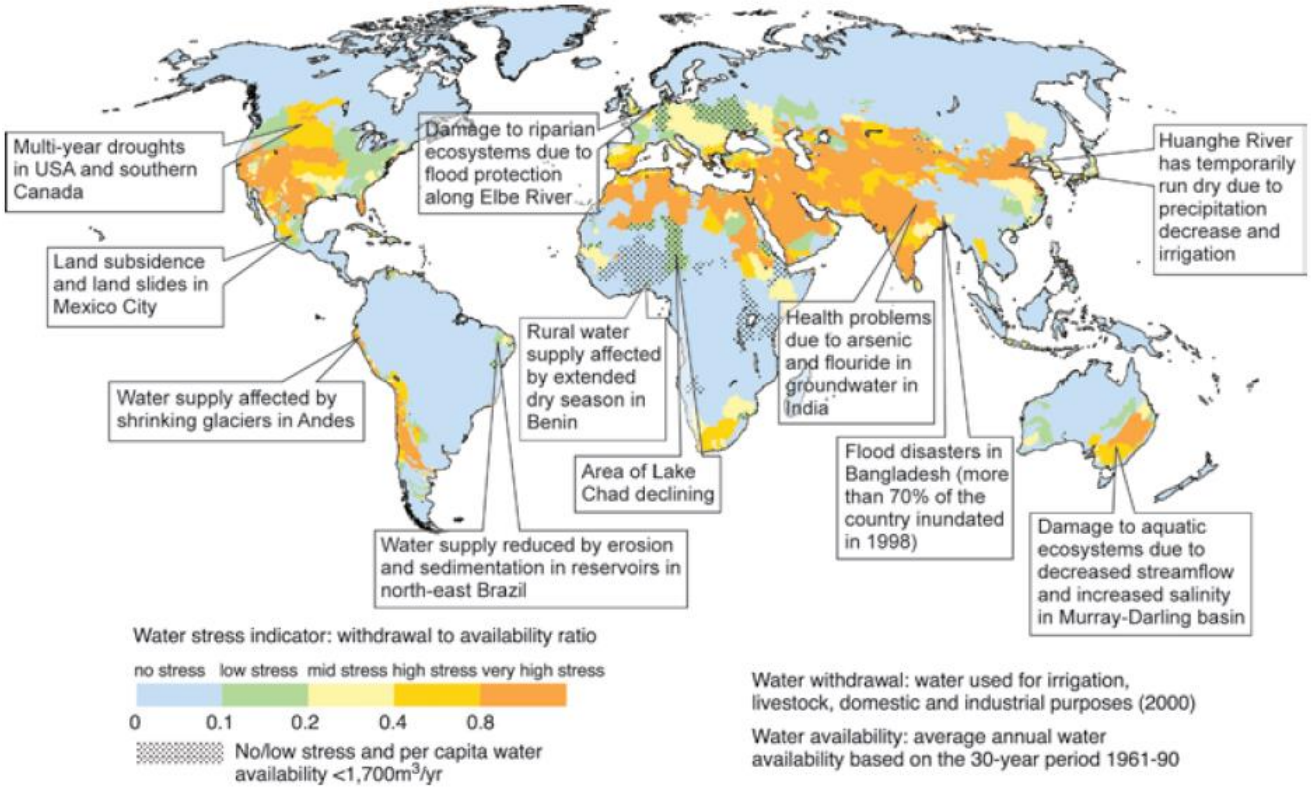

Figure 4. Map of Earth's water-stressed regions (9)

Over the past decades many governments, international bodies like the UN and the WB, have tried to address the rising problems of water shortages, agricultural productivity and population boom by constructing dams. Knowing that "In 2000, irrigation accounted for ~70 % of global freshwater withdrawals and ~90 % of consumptive water use," (9), the efforts we put into dam construction across regions, in order to harness and store waters, come as no surprize. If we look at the continent which has the largest desert area, for example, "Regional inventories include almost 1,300 large and medium-size dams in Africa, 40 % of which are located in South Africa. Most of these were constructed during the past 30 years, coinciding with rising demands for water from growing populations. Information on dam height is only available for about 600 dams and of these 550 dams have a height of more than 15 m. Information on reservoir capacity is available for all inventoried dams and more than half have a capacity of more than three million m^3."

By capacity African dams can be broken down into:

1) Less than 5 % of the dams have a reservoir capacity greater than 1 billion m^3,
2) 10 % between 0.1 – 1 billion m^3,
3) 20 % between 0.01 – 0.1 billion m^3, and
4) 35 % between 0.001 – 0.01 billion m^3.
5) The other 30 % are small dams – or unaccounted for- this phenomenon will be explored more in chapters that follow.

"The majority of dams in Africa have been constructed to facilitate irrigation (52 %) and to supply water to municipalities (20 %). Almost 20 % of dams have multiple purposes, of which irrigation is almost always one of the purposes. Although only 6 % of dams were built primarily for electricity generation, hydroelectric power accounts for more than 80 % of total power generation in 18 African countries and for more than 50 % in 25 countries. Only 1 % of African dams have been constructed to provide flooding control,

according to the World Commission on Dams." (10) This worldwide dam boom was evident from 1950s onwards and has had deep environmental impacts in all the regions, although the great benefits that are provided by dams are not to be questioned. Hydropower, even though very disputed in environmental circles, is a renewable source of energy, and it is much greener than diesel generators that would have been supplying the local households have it not been for the dams.

However, this doesn't always compensate for the environmental impact dams are creating. Firstly, to construct a dam, a region surrounding the river needs to be flooded, this usually involves people being relocated and displaced. This by itself brings a lot of issues and concerns on a socio-demographic level, with lots of people experiencing trauma and never being able to quite fit into their new environment. Sometimes, like in the case of the Aswan High Dam, there are priceless historical monuments that need to be relocated, like was done in the case of Abu Simbel temples. Such manoeuvres should always be the last resort as, for instance, the unimaginable value of the original site will forever would have been lost to Aswan. So the consequences of the historical or world heritage sites in this case, are so extensive that for an archaeologist they are beyond measure. Thirdly come all the environmental impacts which dam construction brings, such as cutting the path of migratory fish species, introducing new species, sediment deposition within the dam and lack thereof below the dam, which further influences the shore and barges' safety. Small earthquakes are created in the case of large reservoirs like Aswan, and the one effect that is very easily noted and monitored in dry regions: the impact dams have had on aquifers.

Aquifers are ground water reserves, created or recharged over thousands of years. They are usually composed of saturated rock through which water can move easily, meaning that they have to be both porous and permeable. Such rock types as sandstone, fractured limestone, conglomerate, unconsolidated sand and gravel are involved. The maps in Figures 5 and 6 present aspects of the global groundwater recharge situation.

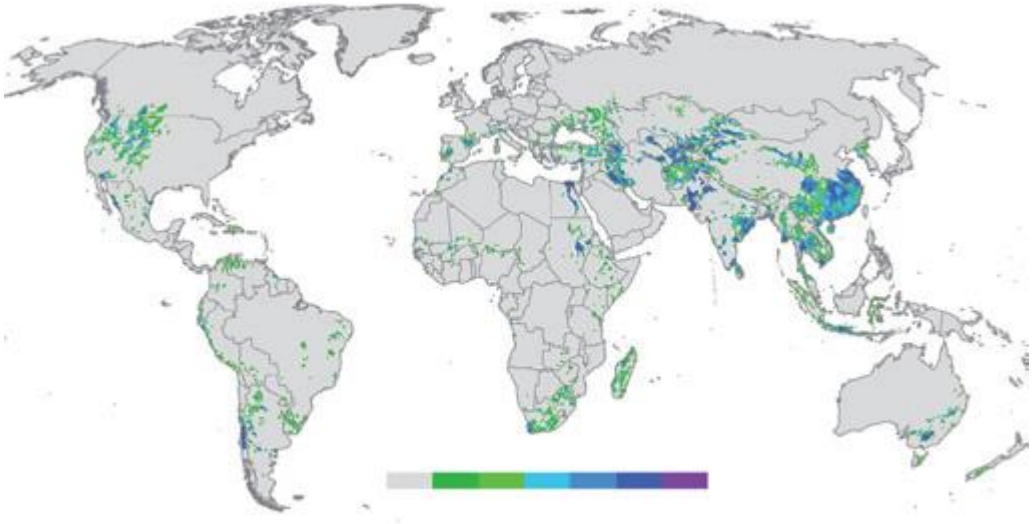

Figure 5. Global map of anthropogenic groundwater recharge rates in areas with substantial irrigation by surface water. (6)

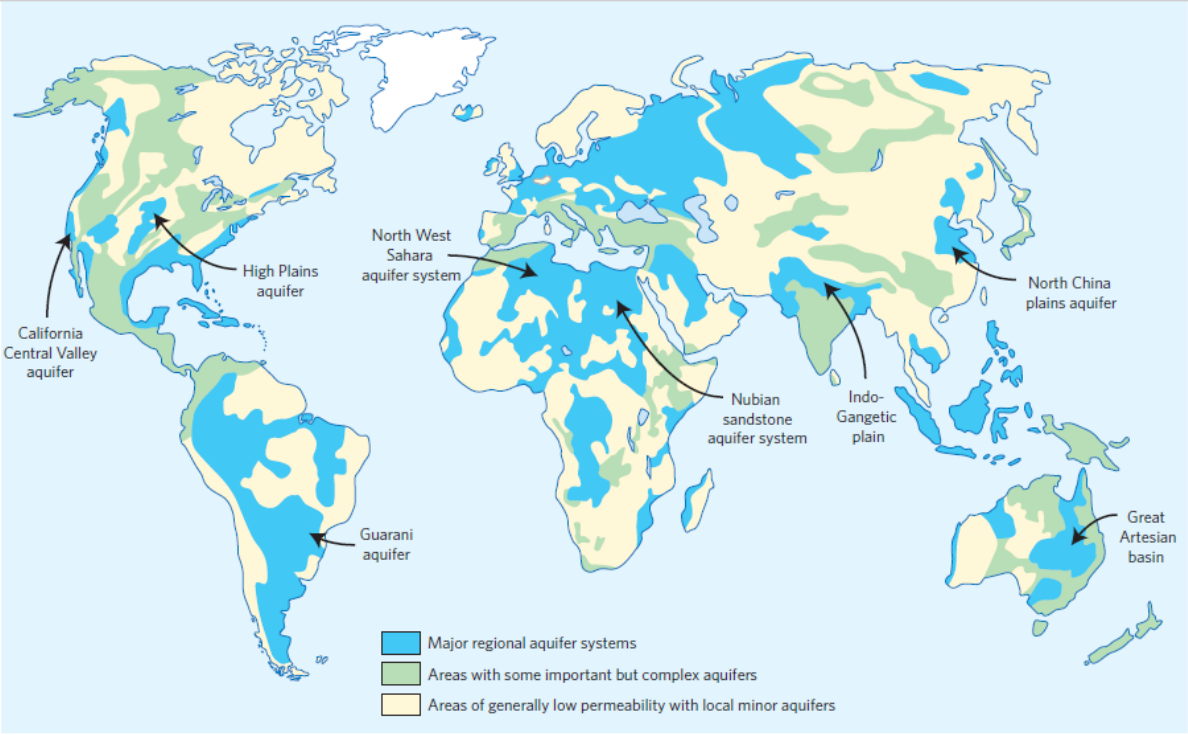

Figure 6. Simplified version of global groundwater resources map (6)

Although fossil aquifers provide a reliable source of water that is resilient to current climate, they are not considered renewable sources of water; groundwater exploitation is unsustainable due to very slow recharge time and it is mined in a manner very similar to oil. "The long-term responses of ground water to climate forcing, largely independent of human activity, can be detected from palaeohydrological evidence from regional aquifer systems in semi-arid and arid parts of the world. Much of the ground water flowing in large sedimentary aquifers of the central United States (High Plains Aquifer), Australia (Great Artesian Basin), southern Africa (Kalahari Sands) and North Africa (Nubian Sandstone Aquifer system) were recharged by precipitation thousands of years ago." And "Stable isotopes of oxygen and hydrogen, together with concentrations of noble gases, suggest that recharge occurred under cooler climates (≥5 °C cooler) before and occasionally during Late Pleistocene glaciation, with further local additions during the Early Holocene. Ground water that was recharged during cooler, wetter climates of the Late Pleistocene and Early Holocene (≥5,000 years BP) is commonly referred to as 'fossil ground water'." (6) This is why aquifers across the globe are considered such a precious water reserve, and one that cannot be taken for granted.

Regardless, much of the Middle East and North African (MENA) countries are highly dependent on fossil waters and are expected to become even more so with the looming climate change. Strong increases in heat extremes are expected in MENA during the 21st century. (11). MENA with its 450 million inhabitants today and expected 650 million people by 2050 (12), is under extreme population pressure in regards to fresh water and food supply. Most of the region has less than 600 mm of rainfall per year (12), with only three major river systems: the Nile, the Jordan River and the Tigris-Euphrates system and it is already considered an arid region. The World Bank has set 1700 m^3/yr of fresh water per capita, as the minimum needed for basic human needs. If a country cannot provide this then it is considered a water stressed country. Some of the main factors increasing the water stress in the region are population growth, predicted rainfall decline, and temperature increase, which will together influence the irrigation stress, adding more pressure to agriculture systems and dependency on world markets. Most of

the region's countries are among the biggest importers of food in the world, with Egypt leading as the number one importer of cereal. The pressure on the groundwater depletion is predicted to rise (even without climate change due to increased agricultural growth caused by growing population), bringing with it increase pressure from salt water intrusion in the coastal regions.

Fossil waters and Climate Change

Waterlogging and increased soil salinity is especially a problem in arid regions where with intense agriculture, followed with intensive mismanaged irrigation we are not only losing great amounts of water but rather destroying the future productivity of our soils with waterlogging and intense soil salinity.

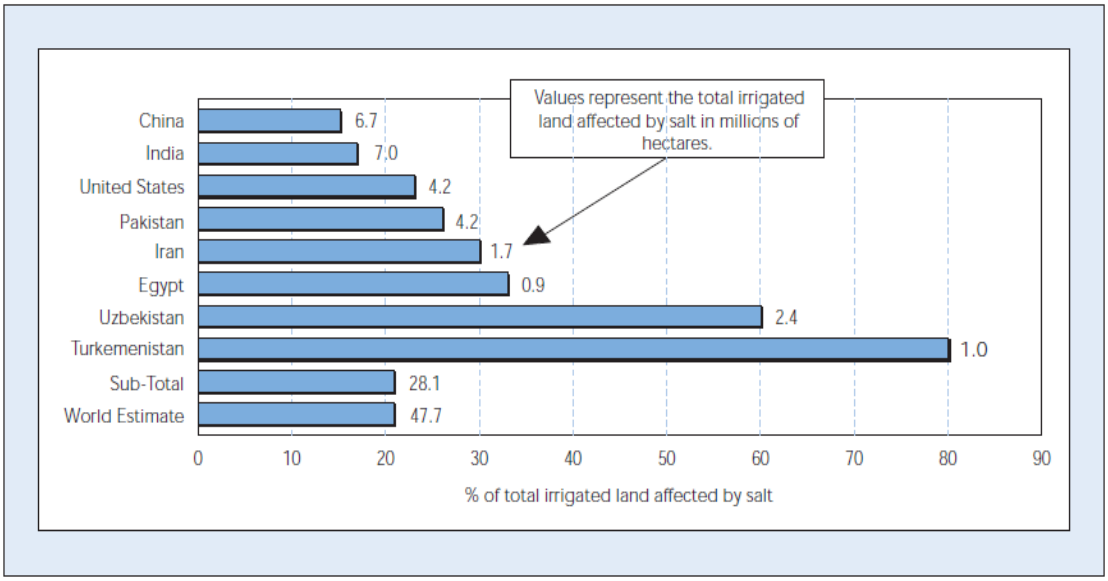

Figure 7. Waterlogging and salinity (8)

Even though in most of the arid world people are highly reliant on aquifers and ground water for all their needs, this is not a sustainable water source and there are many issues aquifers are facing with climate change.

Salt water intrusion in the coastal aquifers was noted across the region as early as 1980s, in countries such as Egypt, Tunisia and Israel, although it is recorded today in many costal zones across MENA. Salt water intrusion is increasing the water stress with turning fossil waters into brackish waters today. This is without taking into consideration the predicted sea level rise due to climate change, which will exert even greater pressure on the fresh water coastal aquifers. Three countries from MENA are on the list of top 10 most endangered countries in the world of 1 m sea level rise in this century. They are Egypt, Tunisia and United Arab Emirates. (13) However, there is so much we have yet to learn about our aquifers and the way they are recharged in a safe manner. "During multi-decadal droughts in the West African Sahel in the latter half of the twentieth century, groundwater recharge and storage rose rather than declined owing to a coincidental LUC from savannah to cropland that increased surface runoff through soil crusting and focused recharge via ephemeral ponds. Much earlier in the twentieth century, LUC from natural ecosystems to rain-fed cropland in southeast Australia and the southwest United States similarly increased groundwater storage through increased recharge, but also degraded groundwater quality through the mobilization of salinity accumulated in unsaturated soil profiles. In both regions, recharge rates under cropland increased by one to two orders of magnitude compared

with native perennial vegetation." (6) However, if in the areas with mostly groundwater-fed irrigation, where there were significant water withdrawals for domestic and/or industrial purposes, no anthropogenic groundwater recharge can occur; leaving the aquifer with a net abstraction of ground water, causing groundwater depletion in regions with insufficient natural groundwater recharge.

In Dubai for example there is a big shift towards groundwater recharging; here the sewage water which has not been used for urban green surface irrigation or other installations is used to recharge aquifers in the desert near Al Qudra Lakes National Park. Although the park itself is supplied with water from desalinated sea water, there are smaller artificial lakes made purposefully to experiment with the recharging.

As our knowledge on aquifers and their behaviour with different types of recharging is very limited, we should focus on detailed documentation from on site and remote monitoring of all the properties and effects, especially taking into account that in such regions like Dubai sand does serve as a natural bio philtre. But to what extent and what cost? Having low depths open water bodies in UAE leads to high evaporation undoubtedly, while recharging the aquifer with processed sewage water does lead to questions about the quality of the new aquifer water even though sand is one of the best bio filters.

From what we know "Modelled estimates of diffuse recharge globally range from 13,000 to 15,000 km3 yr−1, equivalent to ~30 % of the world's renewable freshwater resources or a mean per capita groundwater recharge of 2,100 to 2,500 m^3 yr−1. These estimates represent potential recharge fluxes as they are based on a water surplus rather than measured contributions to aquifers. Furthermore, these modelled global recharge fluxes do not include focused recharge, which, in semi-arid environments, can be substantial." (6) On the other hand, we only saw our first world map of groundwater produced in 2004. "The first global maps of groundwater resources were compiled in 2004, and ground water has recently been incorporated into the Global Earth Observation System of Systems. Nevertheless, the availability of groundwater data (for example, groundwater levels and withdrawals) remains limited. As a result, our ability to evaluate fully the responses of ground water to climate variability and change, to estimate directly groundwater replenishment, and to constrain models and satellite observations, is severely impaired." (6)

This uncertainty coupled with the current climate models do not provide substantial certainty in their abilities to predict the groundwater recharge flows. "Current uncertainty about the impacts of climate on recharge derive not only from the substantial uncertainty in GCM projections of precipitation but also from that associated with the downscaling of GCM projections and the hydrological models used. For a chalk aquifer in England, for example, application of an ensemble of 13 GCMs resulted in projected changes in groundwater recharge for the 2080s of between −26 % and +31 % (ref. 60)." (6) These huge differences in predictions of different GCM projections for a single aquifer are something that puts a question mark on how long can we actually rely on groundwater in the 21st century.

"Groundwater-fed irrigation provides a buffer against climate extremes and is consequently essential to global food security." (6) This has been an often-quoted statement surrounding the issue, but isn't it a bigger problem the sole utilisation of ground water? Don't the observations from the 20th century and Sahel give us an insight into how we should be managing this precious water resource?

If used in a smart, pre-calculated and sustainable way, they could allow for a smooth transition into the 22nd century.

Ground water could give us a safe transition into this new future, but it cannot be taken for granted as it is today. Using more advanced remote sensing and newly available options such as hyperspectral daily satellite monitoring of our planet, can give us greater insights into what is happening with water cycles, which nutrients are being filtered and which are left as crust. Installing sensors in the key aquifers and creating an additional recharge global dataset can allow us to have a pre-calculated analysis on what can be a sustainable use of groundwater and what cannot. Most if not all of it needs to be coordinated and managed by the government and intergovernmental bodies if we are to transition into a new society safely. We know that if you irrigate you can recharge aquifers by creating a forest in the region where the soil is permeable, allowing for the recharge to happen naturally trough soil and tree roots. "Global-scale modelling highlights areas of recent (1998 to 2002) groundwater accumulation through irrigation return flows from surface-water-fed irrigation in the Nile basin of Egypt, Tigris–Euphrates basin of Iraq, Syria and Turkey, the lower Indus basin in Pakistan, and south-eastern China." (6)

However, many aquifers are not only endangered from depletion, insufficient recharge, or inadequate recharge; many now face concrete blockades. Cities are spreading at an enormous pace, (Fig. 7) and are locking more and more porous and permeable ground with concrete. This not only involves the problem with aquifers lying beneath them, it is also fraught with more intense and frequent flash floods that were once recharging them thanks to the abundant forests and deeply developed tree root systems.

On top of that, in the arid and semi-arid regions concrete city expansion adds up to another burning issue: desertification. For example; in the MENA region the problem is being exacerbated with desertification growing not only due to climate change but also due to human factors, like in Egypt. Egypt has had the highest desertification rates globally for a while now, not all due to its geo-location. Contributions to increased rates are evidently due to land mismanagement. Looking at Figure 8 we can see that the Cairo urban sprawl has been growing on some of the most precious arable land in the country, the Nile Delta. Urbanisation has been locking the topsoil, one of the most important carbon sinks, and the first buffer against flash floods, under layers of concrete. This is of course not only the case in Cairo but across the MENA nations and a trend noticeable elsewhere in the world.

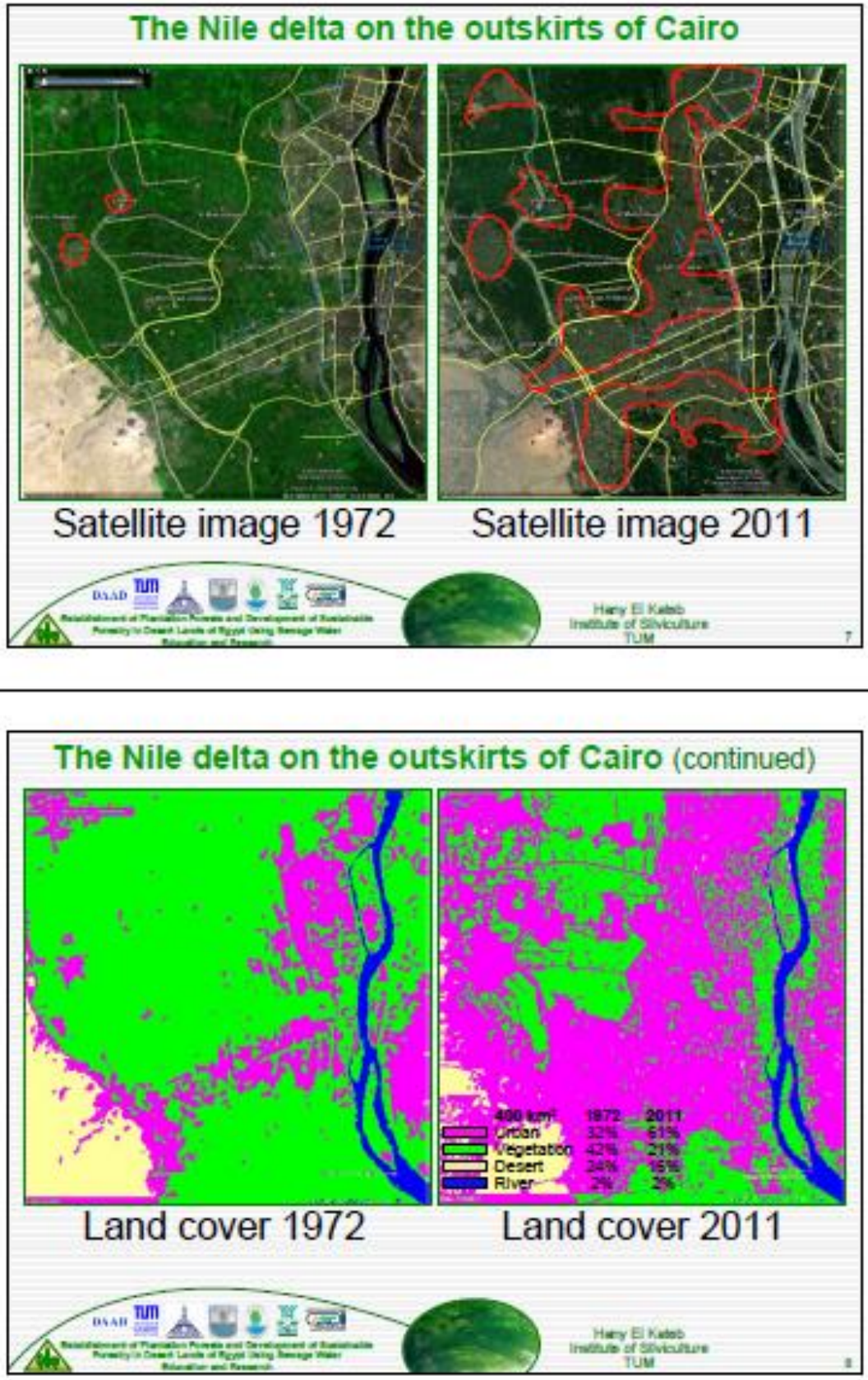

Figure 8. The Nile delta and Cairo 1972 and 2011 (14)

We need to think through and discuss a new model of the city. One that is inclusive and supportive of agriculture, as well as able to have large surfaces of green, tree covered topsoil able to absorb flash floods which are predicted to be nearly the only source of

rainfall for the region as well as the whole Mediterranean basin. Historically we have been focused on using the dams as a buffer for floods in general, however with the rise of flash floods more and more raises concerns regarding the safety of these structures and their potential future use in years of adequate servitude.

Dams an unwanted legacy or a solution?

In an essay "Ancient Irrigation and Buddhist History in Central India: Optically Stimulated Luminescence Dates and Pollen Sequences from the Sanchi Dams", exploring ancient irrigation methods and early dams we can see how, why and by whom the dams were constructed we can learn a great deal on interconnectedness and dependency that we have developed in regards to water management and control millennia ago, which have continued up until present day. "This essay is primarily concerned with the first component of the project, which confirmed the suitability of local sediments for OSL and TL dating methods (an important consideration before designing a longer-term program of research), as well as arming our working hypothesis that the dams were constructed—along with the earliest Buddhist monuments in central India—in the late centuries BC." (Shaw and Sutcliffe 2001, 2003a, 2003b, 2005) The Sanchi survey: background to research Buddhist Archaeology, Urbanisation, and the State Sanchi is one of India's best preserved and most studied Buddhist sites, with a continuous constructional sequence from c. third century BC to twelfth century AD (Marshall et al 1940; Willis 2000). (15)

Here they reflect on some of the more interesting ancient dam features and just how crafted were the engineers of those times to be able to construct structures and even irrigation systems that partly stand today: "Ancient Large Dam: It is the largest dam in the study area, with an average height of 4.5 m, a length of 1 km, and an estimated area and volume capacity of 1.86 km^2 and 3.8 m^3 106 respectively (Shaw and Sutcliffe 2005). It is also the best preserved, with a number of advanced design features including a spillway at the eastern abutment of the dam (Fig. 14) and remains of a monumentalized control structure over the main feeder stream to the west (Shaw and Sutcliffe 2003a, 2005)." (15)

Of course, dating the exact year or decade in which a dam was constructed millennia ago can be a problem regardless of modern-day tools: "Chronology — Dams are difficult to date due to the nature of their construction, with building material often sourced from multiple locations and frequent repairs. Assigning an original context to associated archaeological material is rarely straightforward. The dating of Sri Lanka and South Indian dams has usually relied on inscriptions and constructional (particularly sluice) typologies (Brohier 1979 Fig. 3, Outer facing on Morel Kala dam. 172 Asian Perspectives 46(1), Spring 2007 [1934]; Davison-Jenkins 1997; Parker 1909; Venkayya 1906). For the Sanchi dams, terminus ante quem dates varying between c. first century b.c. and fifth century a.d. were provided by naga (serpent) sculptures located on or near some of the embankments (Shaw 2004a; Shaw and Sutcliffe 2001:68–71, 2003a:84–85).10 Marshall (1940:13) suggested that the dam below Sanchi hill dated to c. third or second century b.c., in keeping with the most prolific building phases at Sanchi." (15)

Dams and their future role in the 21st century

The International Commission on Large Dams, or ICOLD, is an international non-governmental organization dedicated to the sharing of professional information and knowledge on the design, construction, maintenance, and impact of large dams worldwide. ICOLD is one of the rare international bodies (such as hydrocoop.org that

spun out of ICOLD, and NRLD, which adopted the ICOLD norms and definitions on “Large Dams”); which has been monitoring and working with dam construction safety, recommendations and general outcome of dam construction, although only in terms on large dams.

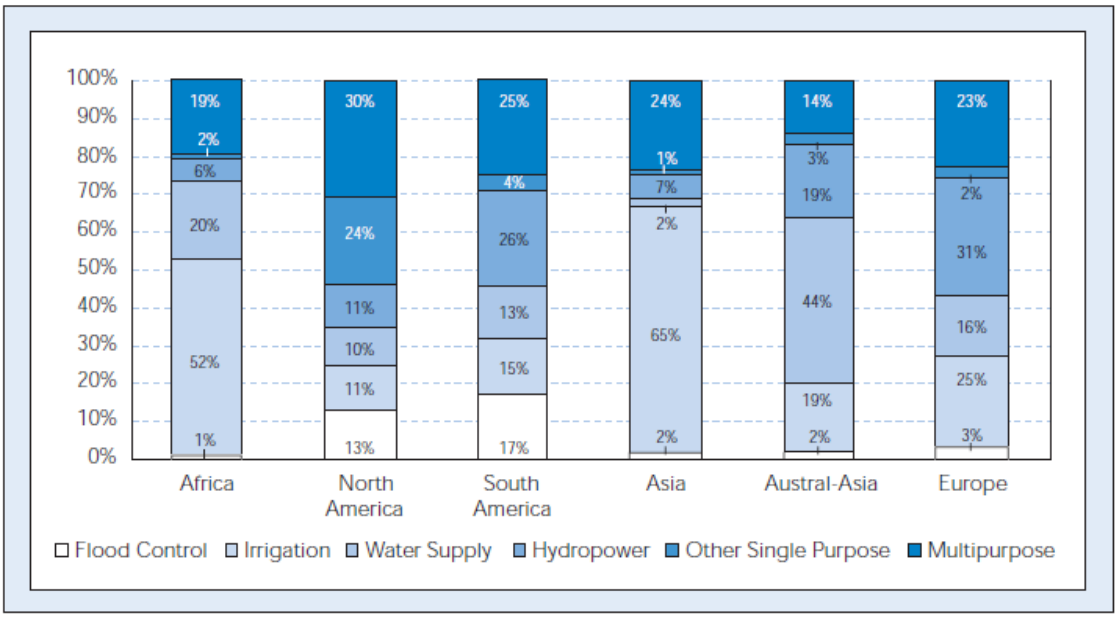

Figure 9. Distribution of existing large dams by region and purpose. (8)

Most of the available literature on dams comes from ICOLD in one way or the other. This is where we get the widely adopted definition on large dams “There are about 50 000 dams higher than 15 m and/or storing over 3 million m3 of water called “large dams”. Other dams are regarded as smaller or medium dams, over 100 000 smaller dams with storage of over 100 000 m3, and small dams, of which we have millions under 100 000 m3 many unaccounted for. Currently there are a few projects underway to account for small dams using satellite imagery; the one the author is acquainted with one, which has been done together with Prof Dr Ramakrishna Nemani from NASA Ecocast division at NASA Ames, California. None of the projects on small dams are available at the moment. This an issue because although the overall storage capacity is close to 7000 km3 of which 98 % for the “large dams”, the smaller/medium and small dams are the ones that will be the most affected with climate change, evaporation losses and rapid dam siltation. The live storage is in the range of 4000 km3 approximately 10 % of the worldwide yearly rivers flow.

The overall area of reservoirs is 0.5 million of km2, which is approximately one third of the area of Earth’s natural lakes. “95 % of the investments in dams and reservoirs were made after 1950. The figures below refer to the large dams and underline their great differences: there is as much difference between a “very large dam” and a “small large dam” as between a nuclear plant and a truck engine. - 50 % of the world’s overall storage capacity is achieved by only 100 huge reservoirs storing over 10 billion m3 each, and 40 % more of the world’s storage is within 2500 reservoirs; lastly, about 40 000 “large dams” store, as an average, 5 million m3. - 600 dams are higher than 100 m; 2000 between 60 and 100 m high; and 10 000 between 30 and 60 high. Half of “large dams” are lower than 20 m. Thousands of large dams are built on very large rivers with spillways capacities of between 1000 and 100 000 m3/s. But over 80 % of “large dams” are on rivers of average yearly flow close to or under 1 m3/s with spillways capacities between 50 and 500 m3/s. (16)

Halting and withholding the natural river flow, as much as 10 % of yearly worldwide river flow, is a huge anthropogenic factor, both in ecosystem view, climate change, as well as natural water cycle lenses. “Between 4510 and 5330 km^3 of water 10.6 % and 12.5 % of the total annual river runoff (42 650 km3 yr–1) is presently stored behind large dams. More than 90 % of this reservoir capacity has been created since the 1950s.” It is easy to imagine how human led activities reduce global river runoff by~328 km3 yr–1, tilting the balance toward greater storage of freshwater on land. This cutback is slightly less than 1 % of the total yearly volume of water delivered by rivers to the oceans 42650 km3 yr–1, being close to around 8 % of the yearly humane utilisation volume of freshwater resources 3414 km3 yr–1. (17)

A splendid visualisation of the world’s dams” capacities can be found on this link http://www.fao.org/nr/water/aquastat/dams/globe_viz.html

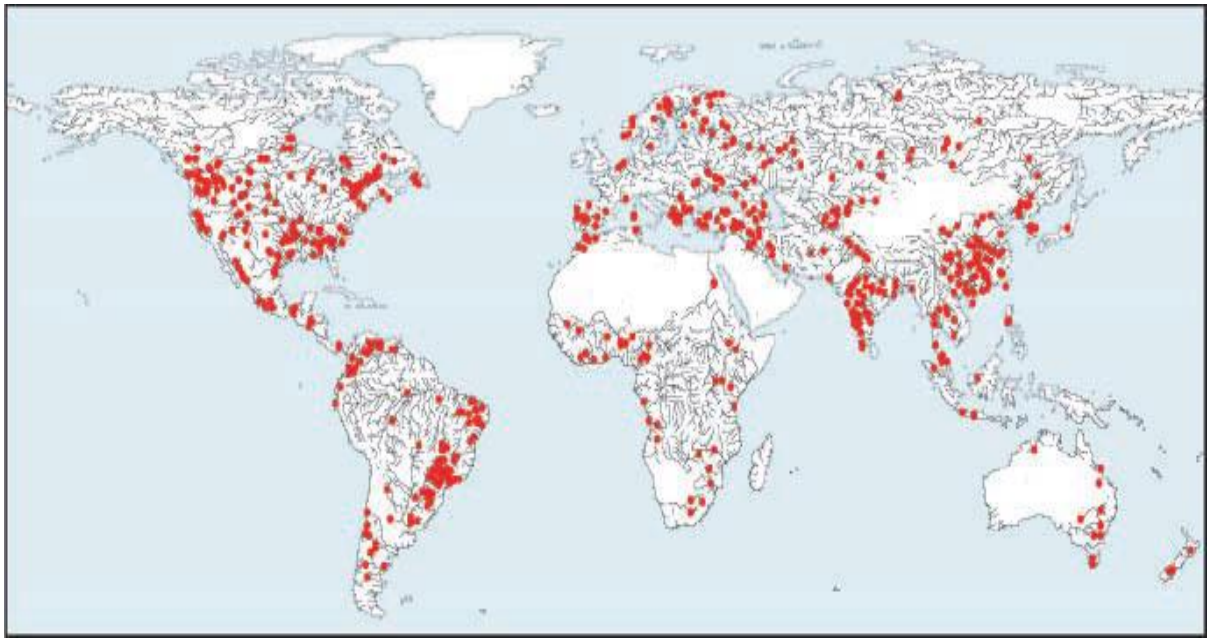

Figure 10. Map of locations of world’s large dams (17)

It is undisputable that humans have made irreversible changes to the Earth’s surface, the natural environment for many animals has vanished in the past century and many animals have disappeared from the face of the Earth together with their environments, their habitats (arguably many scientists believe we are living the Anthropocene, the first human caused extinction event in the history). All this due to human intervention in regards to forests, deforestation, with damming the rivers, hence impacting the flux and flow of water, natural sedimentation patterns and nutrients on local, regional and global scales; with agriculture, creating massive dead zones with agricultural nutrient runoffs and groundwater pollutions. “Construction of dams, urbanisation and use of groundwater have modified river runoff, sedimentation patterns, coastline structure and relative sea level. Changes to timing of nutrient fluxes and sediment load have affected trophic structures within ecosystems. River diversion and modified seasonal variability of water levels have affected the health of coastal wetlands, mangrove and coral reef communities as well as leading to changes in shoreline profile and ecosystem composition of rivers, estuaries and coastal seas. Awareness of anthropogenic impacts needs to lead to technological innovations to manage the system as it exists, and to minimise further degradation of coastal systems.” (17) Could we somehow utilise the piled-up problems we have created by building dams on every single stream that was

available? Can we even account for all the dams we have constructed over the past century? Could freeing the rivers be a potential solution to catastrophic environmental consequences we are facing today? Or would this create an even bigger problem with intense sediments entering the rivers, seas and oceans causing potential harmful and unprecedented algae blooms and dead zones never seen before? With dam decommissions and demolitions, producing added CO^2 in the atmosphere, can we afford this? Or could this problem potentially be a solution we were seeking for as climate engineers? From engineers to engineers; fixing what we can with minimum to no impact to the environment?

One such technological innovation will be proposed in this thesis, addressing the rising problem of dam siltation worldwide, especially taking into consideration the climate change and the future water shortages which will be caused by both.

Dam Safety and Siltation as a rising problem in the face of the Climate Change

When it comes to utilisation of large dams, and their performance (in this regard high or low siltation is always considered) ICOLD has a very biased view. This has been a troubling factor for the author during the whole research phase. ICOLD has the most comprehensive available data set but it has to be taken into consideration with a grain of salt. The same is true with respect to publications of the IADC (International Association of Dredging Companies). Not only this, but ICOLD has sometimes been quoted in the literature as if it is the one and only source of truth; all this coming from different articles but leading back to the same dataset, making it very hard to be objective. ICOLD has established itself as the main source of truth for the industry. Without a real competitor from any sector, ICOLD has dominated the large dam regulatory and supervisory norms and regulations for years now. Most of the people in ICOLD are great construction engineers and other engineers focused on the dam industry. It seems that consequently they cannot help but see dams as a good thing and a good solution.

The present author is of the opinion that there needs to be at least two more strong players in the dams regulatory and observatory market, preferably from beyond the western world. In the contemporary situation, there is little industry change towards safer and more environmentally friendly engineering.

This was one of the key factors why the present research was focused upon the Aswan High Dam Reservoir and did not take into account a broader perspective. The AHD Reservoir has a comprehensive local data set on all accounts, including the siltation rates monitored by several bodies including two state institutions, hence not only relaying on ICOLD.

However, the problem is much larger than that one dam alone. Siltation reduces the storage capacity of reservoirs, reducing first the dam's ability to produce hydropower, as with each cleaning of the turbines production needs to stop and their efficiency before cleaning would have been reduced. Not only this, but siltation directly influences the water availability for the local communities. There is less available volume for water and hence there is the less available water for consumption. The same goes for irrigation. This has led many communities to abandon their villages once the dam has been heavily silted. With no access to potable and irrigation water, they were forced to relocate in large numbers, becoming the "first climate refugees". Such as has often been the case in the developing world. After the siltation has taken over most of the dead zone it can become a structural threat, sometimes even before that, causing the

most dreaded of all the consequences of dam building, the dam failure. China has on average 68 dam failures each year (18) on account of many factors out which siltation is always one of them.

If observed from a more global perspective siltation ultimately takes over the volume, which in turn decreases the volume of water that otherwise would have been withheld from sea-level rise. The extension of this logic would be that the siltation is helping the sea level rise in a sense. “Although some Asian reservoirs are filling up at the rate of 2 % per year, a sampling of siltation rates from many dams around the world suggests an average value of around 1 % per year. Siltation has decreased the storage capacity by as much as 45.1 to 53.3 km3 or 1.13–1.33 km3 per year since the 1950s globally. The impacts of dam siltation not only effect the reservoirs severely, shortening their useful life span, but it considerably reduces sediment delivery to many coastal regions, such as Louisiana, Mississippi, USA and the Nile Delta, Egypt, resulting in severe shore and delta erosions.” (17) The worst manmade disaster is perhaps the infamous “River Dragon” in China in 1975 one August night due to a once in a 1000 years storm, over 62 dams broke instantly killing more than 85,000 people and effecting the lives of 11 million people in that province.

“Altogether 62 dams broke. Downstream the dikes and flood diversion projects could not resist such a deluge. They broke as well and the flood spread over more than a million hectares (2.5 million acres) of farm land throughout 29 counties and municipalities. One can imagine the terrible predicament of the city of Huaibin where the waters from the Hong and Ru Rivers came together. Eleven million people throughout the region were severely affected. Over 85 thousand died as a result of the dam failures. There was little or no time for warnings. The wall of water was traveling at about 50 kilometres per hour or about 14 meters per second. The authorities were hampered by the fact that telephone communication was knocked out almost immediately and that they did not expect any of the ‘iron dams’ to fail.” (19) These types of millennial flood prediction were not made to take into account climate change, and as witnessed in the Balkans in 2013, then 2014: the millennial floods are becoming a norm with the growing recurrent events such as flesh floods. The two so called “Iron Dams” the Banqiao and the Shimantan Dams, were meant to be indestructible. However, they failed destroying everything in their path.

From this brutal example we can conclude that dam construction and engineering plays only a partial role in dam safety and that dam management and maintenance plays the other half. If extrapolated, perhaps an even greater one in the face of climate change and unpredictable weather patterns. Hence having access to ever better and more accurate tools in predicting dam safety will play a crucial role in future dam maintenance.

Desilting the reservoirs, as part of dam maintenance operations, as well as many other available options for flushing, slushing or similar actions related to sediment removal are usually very expensive and only used in very regulated watercourses, predominantly in the instances of large dams and locations in the developed world (And let us not forget that we don’t even have an accurate count of small dams).

This is why ICOLD has been putting dam construction back on the agenda of the World Bank, focusing on new dam constructions methods. Though the industry has been in decline since 70s and with a very bad environmental reputation since 90s, abandoning the old dams is not an uncommon practice nowadays. The World Bank are predicting that “the total present water storage, which is presently close to 7000 billion m3 will probably increase only by about 3000 billion. The average cost per m3 of reservoirs built

in the 21st century will be much higher than between 1950 and 2000 because the yearly investment may remain the same for 100 years instead of 50 years and for a storage of 4000 km3 instead of 7000 km3. The overall benefits of dams during the 21st century will be five times what they have been since 1950; Technical, economic and environmental problems, that we will address in the next issue of The Dams Newsletter, should not prevent the implementation of such useful dams. 90 % of the relevant potential is in countries which urgently need development and safe water."

It is undisputed that many developing countries need urgent energy, water and irrigation stability, that many developing countries need protection from rising threat of flesh floods, however the question raised here is have we not learned anything from our past? Can we not look into the future forecasted by many reputable research institutes on flash floods, glacier melting, and torrential streams? Should we totally disregard what IPCC has been saying? ICOLD, as the main authority on dams, is of the opinion that "There ecosystems were not destroyed, they were transformed." (16) How can we secure the proper management and maintenance of new dams? Can the safety and efficiency of new dams even be compared to the easy, cheap and available solar energy, solar desalination plants or solar air to water harvesting operations? Is there any space for hydropower and dams in the 21st century?

If construction of dams for hydropower can be justified, then knowing that "In the 20th century 80.000 TWh of Hydropower have been produced. In the 21th century, the plants completed in 2000 will produce about 250.000 and the new one is about the same, the total (500.000 TWh) being six times the production of the past Century. For environmental and resettlement reasons, the water storage per yearly kWh will probably be further reduced for new schemes, particularly in populated areas of Asia and be lower than in the last decade, and thus well under 1m3/kWh." (16) With the solar price decline above 200x, does it even make sense to invest in hydro solely for energy production? Or water harvesting in costal zones?

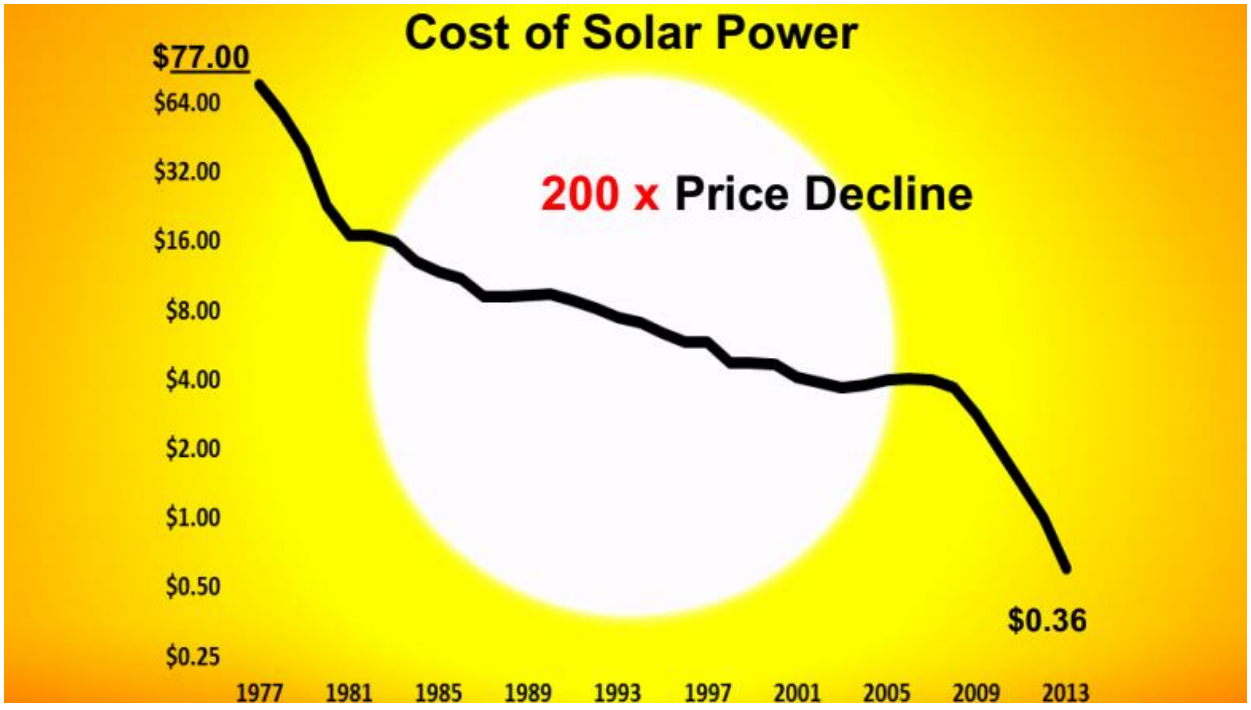

Figure 11. Cost of Solar Power 1977-2013 (slide from the "Energy" Class NASA Ames, SU, CA, USA Ramez Naam summer 2017 GSP; authors private collection)

As far as it goes for irrigation only dams, “Most irrigation storage by dams is within few countries: China, India, U.S. and former U.S.S.R. The total relevant dams” storage for irrigation is in the range of 500 billion m3. Ten other countries (Australia, Brazil, Egypt, Iran, Mexico, Morocco, Nigeria, Pakistan, South Africa and Thailand) store altogether for irrigation about 200 billion m3. The overall irrigation storage of other countries is about 100 billion of which an important part is in Southern Europe. The overall storage for irrigation seems thus under 1000 billion m3;” 80 % of which is in non-industrialized countries. (16) However the evaluation of extra water storage for irrigation in the 21st century is a tough one, since the need for water for food and agricultural expansion will more than double within 50 years, and knowing that 40 % of our food comes from 20 % of our available agricultural land, and now looking at the dam statistics on sedimentation rates and the one about large dams; one can imagine how endangered our food supply is if it depends on small dams easily siltated in Asia predominantly. Perhaps solar, air to water technologies and many other water harvesting options should be closely considered before opting for dam construction in 21st century. As pointed out in ICOLD periodical:

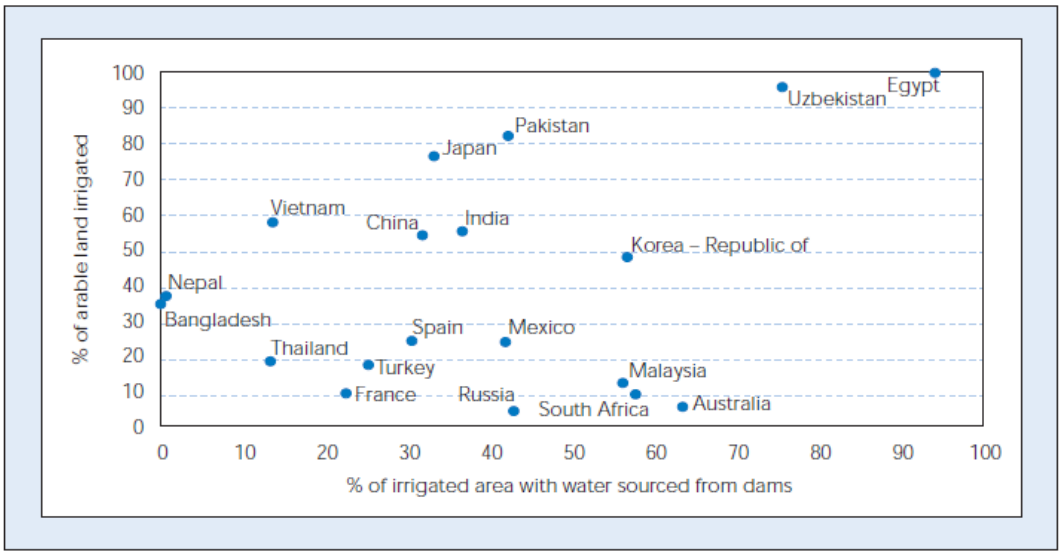

Figure 12. Agricultural land irrigated from dams by selected country (8)

Since many countries will keep or develop their agriculture for maintaining employment and avoiding import of food; the prosperity of many world areas is linked with irrigation. Greenhouse effects will probably increase the water needs for agriculture.

“Sedimentation reduces irrigation dams” storage by a few billion m^3/year.” (16) In this publication ICOLD basically hand picks which of the climate change effects to take into consideration, focusing only on those which are pro dam construction. However, this will in many ways depend upon our future developmental path. Will we continue with the “business as usual scenario” or will we try creating newly modelled self-sustaining cities able to store water and have their own agricultural needs met with the advancement of exponential technologies, or perhaps focus on storing the water and preventing flash floods, topsoil wash off and erosion? Or will we be restoring more forests, with agroforestry integration in suburban zones and/or similar, as it is already put into legislation in some of the Southern European states, where flash floods are the biggest threat in the face of climate change? On the other hand, some countries such as Turkey, Iran and Morocco are giving a lot of attention to irrigation dams. However, the greatest potential in new dam instalments as seen by ICOLD is “An extra storage 2000-2050 of about 2000 billion m^3 for a production increase of 2800 TWh/year seems a

reasonable evaluation. Half of the remaining potential is in five countries (China, India, Brazil, Russia and Congo)." (16)

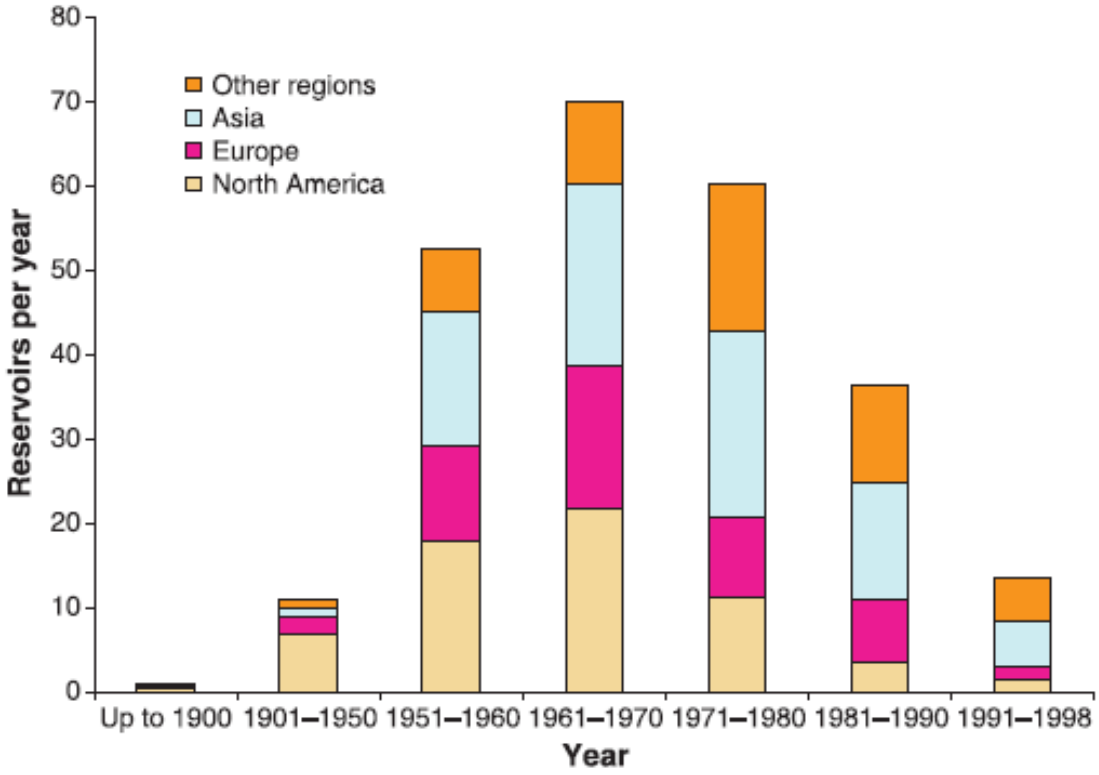

Figure 13. Construction of large reservoirs worldwide in the 20th century

"Average numbers of reservoirs with volumes greater than 0.1 km^3 built by decade, through the late 1990s, are normalized to dams per year for different periods. Note that there was a peak in construction activities in the middle of the 20th century, tapering off toward the end of the century. The period 1991 to 1998 is not a complete decade; note also that the period 1901 to 1950 is half a century. "Other regions" include Latin America, Africa, and Oceania." (20)

Which takes us to China and India, and the Himalayas, the rooftop of the world, the water towers for more than half of the world's population; the world's the eternal spring. A recently published comprehensive report from the International Rivers on damming the Himalayas, "Mountains of Concrete: Dam Building in the Himalayas," gives an objective overview of what we are to expect if we proceed with the plans developed for this region. The Himalayas store great amounts of water, with the ten largest rivers originating in the Hindu Kush Himalayas alone supplying water to over 1.35 billion people (20 percent of the global population). (21) And about 40 percent of the world's irrigation is supported by flows originating from large mountain systems. It is easy to see how their high slopes and the fast-moving rivers present huge potentials for generating hydropower. India, Pakistan, China, Nepal and Bhutan have initiated enormous plans to build several hundred dams to realise this potential. Irrigation is another high potential for this region, which is causing tensions between India and China, "…large inter-basin schemes are planned to irrigate arid regions, which would raise the number of people depending on water from the Hindu Kush Himalaya region to more than two billion. As demand increases, the potential for conflict over the use of mountain water grows both within and between countries. For example, in 1995 alone, the distribution of water from mountain areas was a contributing factor to 14 international conflicts, plus countless disputes within national borders." (21)

At the same time these countries have growing needs for increased energy and electricity demand, and some of them suffer from severe shortages and even crises with their ever growing populations. “All of them face very real and very difficult questions of how to meet these needs. Hydropower dams in the Himalayas are being advanced as a solution to meet a substantial part of these requirements.” (22) By far the most serious issue, as neatly pointed out in the report by the International Rivers, is that of climate change and its impact on the Himalayas. “The impact of Climate Change is already being felt much more in the Himalayas than in other parts of the world. This is resulting in the accelerated melting of glaciers and the depletion of the massive water store of the region. There are real fears that the “abode of snow” would no longer be left with any, turning “the snow-covered mountains into bare, rocky mountains and dynamic glaciers…into lifeless rubble.” This would have tremendous impacts all the way to the Indo-Gangetic Plains. The impact of climate change will be aggravated by the construction of hundreds of dams. As glaciers melt, water in the rivers will rise, and dams will be subjected to much higher flows, raising concerns of dam safety, increased flooding and submergence. With the subsequent depletion of glaciers there will be much lower annual flows, affecting the performance of such huge investments. Climate change will also increase the threats of Glacial Lake Outburst Floods (GLOFs) and possible cascading failures of downstream dams. Unfortunately, dam construction is being planned and carried out with hardly any assessment of these impacts.” (22)

Creation of more storage as an answer to fluctuating flows in the face of climate change is not only needed in the case of Himalayas, but all glacial mountain ranges. This issue of building more dams to hold, preserve and utilise the melting glaciers “…ignores the fact that climate change is going to increase the threats to dam safety, including the risks of catastrophic events like GLOFs. Hence, building more dams is likely to be a high-risk policy choice. Indeed, given that the glacial melt feed to the rivers is likely to decline over the longer term, the very logic of building new and bigger dams is questionable, as they may not deliver the designed benefits. Building huge storages to catch occasional high flows will be an expensive measure…” “The cascading effect of a GLOF leading to a dam failure can only be imagined. Apart from the dangers of GLOFs, climate change may impact other cryogenic (very low temperature related) processes like avalanches and debris flow. The melting or shrinking of permafrost is likely to impact slope stability and erosion processes. All of these have implications for the safety and performance of dams and other infrastructure projects.” (22) The frequency of such disastrous events like GLOFs is very likely to increase with climate change, further raising risks to dam safety. Sedimentation, already a problem for dams in the Himalayas, is also predicted to intensify. “The big dam planners seem to have adopted an ostrich-like attitude to the impacts of climate change on the Himalayan region.” (22)

The future of water safety for nearly 1/3 of human population looks pretty dim with such attitudes coming from some of the main players. And although China has done a lot of damage to speed up climate change, in the recent years they have put tremendous work into changing this, especially now with the opening of the Chinese Carbon Market in 2018, with massive afforestation and reforestation projects long underway. We can only but hope that soon they will see the futility of such *an ostrich-like attitude* towards future dam safety and construction.

Although the dams in Africa don’t face the same threats as the ones on the Himalayas, floods are always a concern in planning for dam construction.

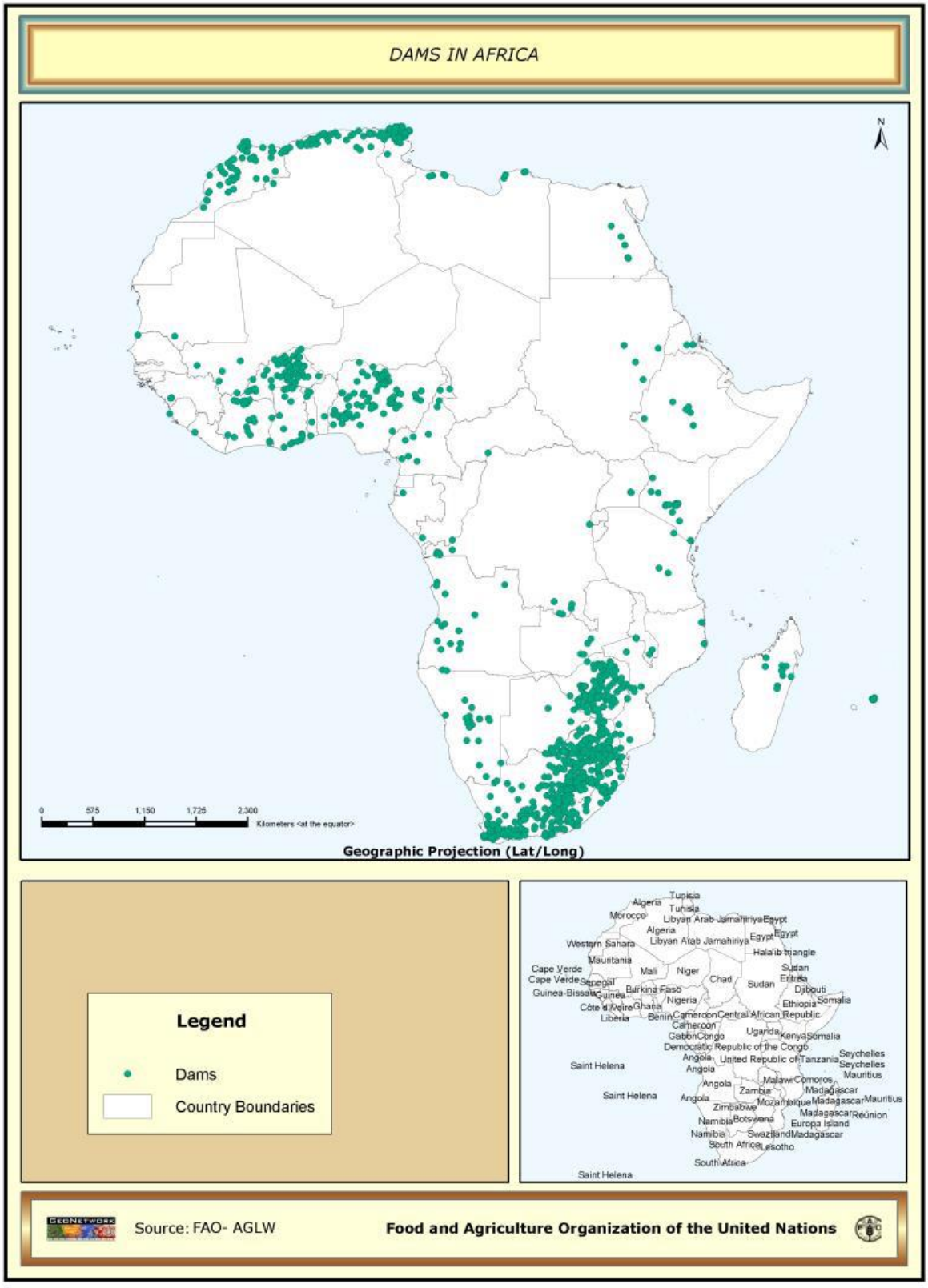

Figure 14. Dams in Africa (10)

Dams in Africa are multipurpose dams, usually constructed to provide flooding control, according to the World Commission on Dams. “Considering dams with a reservoir capacity of over 1 billion m3, Africa counts 54 of such dams with a total reservoir

capacity of about 726 billion m3, or almost 90 % of the capacity of all dams in the inventory. Of these dams, 20 are multipurpose dams, mainly used for both hydroelectricity and irrigation, 22 are used mainly for hydroelectricity and 12 mainly for irrigation. Eight of these large dams have a reservoir capacity of over 10 billion m3 each and three of over 100 billion m3 each (Kariba on the Zambezi River with 188 billion m3, Aswan on the Nile River with 162 billion m3 and Akosombo on the Volta River with 148 billion m3). The reservoir capacity of these three dams represents almost 70 % of the total capacity of the 54 dams. While the Kariba Dam and the Akosombo dam have been built for hydroelectricity, the Aswan Dam was built for irrigation in Egypt." (10) The distribution of the large dams in Africa within the major river basins is shown in Figure 14.

Dams build on major rivers, especially on mountainous rivers, which carry a lot of sediment with them, such as the Nile, the Amazon, the Yangtze or any other of the Himalayans" rivers create a special set of environmental problems with the dam construction, aside from the imposing threat of dam failure. This is the decrease in sediment supply to the oceans. "Between 1951 and 1982 dams were being constructed at a rate of 900 per year. Prior to 1950 there were only eight dams in China; by 1982 the number had increased to 18,600, or 55 % of the world total." (17)

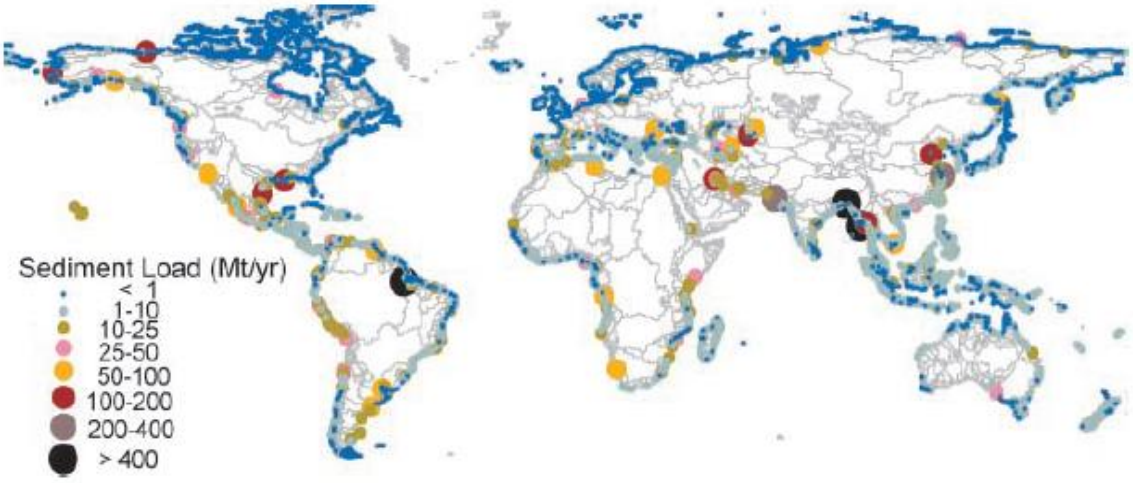

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Figure 15. Sediment flux. Predictions of the sediment load of rivers with basins larger than 25000 km2 (Vörösmarty and Syvitski, unpubl. data 2002).

Much of the world sediment is shed from the rivers that drain the Himalayas and the Tibetan Plateau. (17) The environmental, social, economic, geomorphological, political and strategic impacts of changing the natural sediment flows go far beyond what we expected in the mid-50s and 70s when the greatest dam boom was happening. The United Nations tries to account through different bodies all of them, this is how "…in 2001 the United Nations launched a four-year study involving more than 1,300 scientists from 95 countries, to examine the issue of biodiversity and the ecosystem. In 2005 the Millennium Ecosystem Assessment (MA) was published. The MA marked a turning point because it provided a methodical, clear and compelling analysis of the state of the Earth's ecosystems; describing ecosystems as the Earth's "life-support system", providing humankind with essential "services" which were specifically enumerated. It also provided guidelines for decision-makers and people in general. (23)

A few years earlier the World Commission on Dams (WCD) was formed to try to address all of the concerns on dam safety and siltation raised in this literature review, and also environmental concerns rising from dams" construction, existing dams and future dams" decommissionings. It was a global multi-stakeholder body initiated in 1997 and disassembled in 2001, by the World Bank and the World Conservation Union (IUCN) in response to growing opposition to large dam projects. The WCD Report on the guidelines for the construction of new large dams is available in full on the WCD website (www.dams.org). "In brief, the Report's recommendations include a set of five core values for future decision-making (equity, efficiency, participation, sustainability and accountability); a rights and risks approach for identifying stakeholders in negotiating development choices and agreements; seven strategy priorities for water and energy resources development (public acceptance, options assessment, addressing existing dams, sustaining rivers and livelihoods, recognising entitlements and sharing benefits, ensuring compliance and sharing rivers for peace, development and security); and a set of criteria for assessing compliance and 26 guidelines for review and approval of projects at five stages of decision-making." (24)

The most important to note from one of the reports from WCD are the Conclusions listed as below from the original report:

"The following inferences can be drawn from this review:

1. Dams and their environment interrelate with a high degree of complexity. Responses of river ecosystems to dams are multiple, varied and complex. They depend not only on the dam structure and its operation but also local sediment supplies, geomorphic constraints, climate, and the key attributes of the local biota.

2. Dams cause changes in abiotic steering variables related to hydrology, geomorphology and water quality. These changes impact on the biotic components (including people) of river ecosystems.

3. The impacts of a dam may occur a great distance from where it is built. The environmental consequences of impoundment cannot be considered in isolation but must be considered within the context of the whole river ecosystem including the coastal zone.

4. Despite the research that has been conducted to date, it is in many cases impossible to predict, even with site specific studies, what the precise impacts of a dam will be. This is particularly true of the second (and third) order impacts that may not occur until many years, maybe even millennia, after dam closure.

5. There is a need for fundamental research linking abiotic processes to changes in ecology, particularly in tropical environments, where much of the remaining potential for "new" river regulation resides. For all new large dams pre and post construction studies should be conducted in order to assess the environmental impacts and to determine the effectiveness of mitigating measures. Since the time-scales for ecological and morphological change are of the order of centuries observations will need to be extended well beyond the 25 to 50 years that appears to be the limit of nearly all present studies.

6. There is a need for long term datasets from around the world based on studies in which measurements are made in a systematic and comparable manner. Such studies must collect pre and post dam data and must incorporate details of dam operation (e.g. release regime – both operating rules and actual releases). Information needs to be

collected not only from the vicinity of the dam, but from throughout the catchment in which the dam is located.

7. Worldwide variations in climate, runoff regimes and sediment transport provide the basis for attempts to generalize the impact of dams on ecosystems. However, further study is required in order to provide more than a broad prediction of the impact of a planned dam on upstream and downstream ecosystems.

8. Simple to determine indicators of likely environmental impact, proposed by Ledec et al (1997), enable typical traits of environmentally preferable and undesirable dam sites to be ascribed. These suggest that in general deep reservoirs in the headwaters of rivers with numerous downstream tributaries will be less environmentally damaging than shallow lowland reservoirs with few downstream tributaries.

9. The degradation of river ecosystems, as a consequence of river regulation, can have profound economic and social implications. In the past failure to take into account the cost of these consequences has resulted in the benefits of many dams being overstated.

10. Economic and social impacts are diverse and widespread and neither costs nor benefits are evenly distributed amongst stakeholders.

11. There is a need for more comprehensive methods of economic analysis which incorporate a measure of all costs and benefits, including all positive and negative externalities from non-marketed ecological services.

12. For sustainability to be achieved in its fullest sense, social impacts should be given the same weighting as economic and environmental impacts, subject to the maintenance of ecosystem integrity.

13. There is a need for more equitable distribution of the benefits gained from a dam. It is essential that those people directly affected by its construction benefit. Resolution of conflicts will to a large extent depend on the political will to establish new institutional mechanisms that promote equitable transfer of benefits.

14. Environmental standards relating to the impacts of dams are primarily limited to the recommendation that environmental assessments should be conducted. The only defined thresholds of acceptability are those that concern water quality. Although some general principles can be drawn on dam setting, construction and management, impacts are inevitably very site specific and therefore recommendations and standards must take this into account.

15. The position of proponents and opponents of large dams is perhaps less polarised than is popularly believed. However, key areas of disagreement remain particularly with regard to the evaluation of true costs and benefits of dams and the distribution of those cost and benefits between different sectors of society.

16. In the past dams have been built largely to provide water supplies at times when water is naturally scarce, to provide “clean” power and to reduce the devastating effects of floods. These are all worthy reasons for river regulation but, as the ecosystem approach indicates, the effects of impoundment for natural ecosystems cannot be ascribed secondary status without dire long-term consequences for human well-being.” (25)

The consequences of dam siltation and how do we deal with it now?

When taking into consideration, all the possible impacts dam construction will have on its surroundings; that river system, the river's delta and a sea also needs to be taken into account. To do so one needs to understand fully the sedimentation process which occurs over time in these newly formed environments. Observe Fig 13 and 14 accompanying this insightful explanation from Dr Bednarik: "Sediment transport is also affected by damming (Petts 1984, Kondolf 1997, Poff and others 1997). Obstruction by dams disrupts the movement of sediment in rivers and changes a river's structural habitat (Kondolf 1997, Wood and Armitage 1997). Storage dams slow the water velocity of the river, causing sediment to settle in the inflow of the reservoir. Where the river no longer has the power to transport boulder, cobble, and other large particles, it results in an aggradation (raising) of the streambed upstream of the dam (Petts 1984, Fan and Springer 1990). Finer particles, such as sand and silt, settle closer to the dam itself and can ultimately fill the reservoir, limiting hydropower generation or water storage (Petts 1984). These fine particles also fill in valuable cobble and boulder habitat, rendering it unusable for many organisms. Changes in sediment transport can decrease biotic diversity. Fish can have physical habitat requirements that fluctuate seasonally or by their age class (Rabeni and Jacobson 1993). Salmonid fish depend on a variety of sediment types for spawning (Kondolf 1997). The size of the sediment needed can vary with the size of each type of fish and its strength in moving sediment with its tail (Kondolf and Wolman 1993). Retention of sediment by the reservoir can also cause sediment-low water to be released downstream of the dam, limiting the sediment and nutrients available for organisms (Church 1995, Kondolf 1997). These "clear-water" releases can also cause erosion downstream of the dam as the river attempts to regain sediment equilibrium (Kondolf 1997). The channel becomes coarse, or armoured, riffle–pool sequences vanish, and bank collapses and riparian losses may result." (26) We can make a distinction between types of reservoir sedimentation as explained by Dr Kamaleldin E. Bashar in "Nile Basin Reservoir Sedimentation Prediction and Mitigation".

Types of Reservoir Sedimentation:

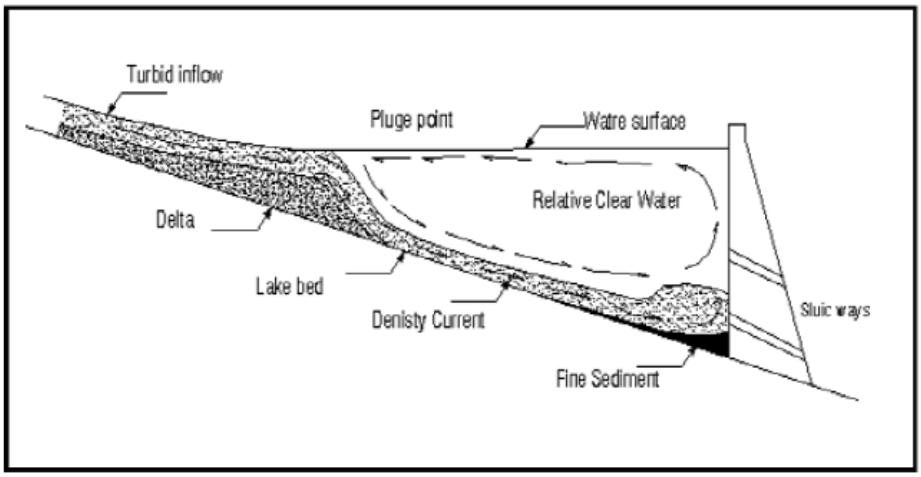

Figure 16. Types of reservoir sedimentation (27)

Sedimentation levels in Africa today and their origins

Region	Number of large dams	Storage (km^3)	Total Power (GW)	Hydropower Production in 1995 (TWh/yr)	Annual loss due to sedimentation (% of residual storage)
Worldwide	45,571	6,325	675	2,643	0.5 – 1
Europe	5,497	1,083	170	552	0.17 – 0.2
North America	7,205	1,845	140	658	0.2
South and Central America	1,498	1,039	120	575	0.1
North Africa	280	188	4.5	14	0.08 – 1.5
Sub Saharan Africa	966	575	16	48	0.23
Middle East	895	224	14.5	57	1.5
Asia (excluding China)	7,230	861	145	534	0.3 – 1.0
China	22,000	510	65	205	2.3

Figure 17. Worldwide Storage, Power and Sedimentation (RESCON Manual Volume I, 2003, After White, 2001)

What jumps out from this table is that China and the MENA region are leading in sediment creation in the world, with China losing 2,3 % annually and MENA 1,5 %, while the rest of the world has a maximum at 1 %, like the rest of Asia is, when excluding China. There are many causes that can be contributed to these high levels of sediment deposition, from poor regulations, basin mismanagement, lack of flora, and etc. However, one that stands out and is easy to spot as a common trait of both MENA and China. There are spread three of the largest deserts in the world: the Sahara and Arabian deserts being warm and the Gobi Desert being a cold desert in China, by size listed as 3rd, 4th and 5th sequentially, if we include Antarctica and the Artic as number 1 and 2.

To understand better the origin of sediments in these water bodies, we must look at the overall picture, and this means looking into the basin of each river. Further knowing the landscapes through which a river has to pass in order to rich its final destination that was once the sea, but it is now in most cases first a reservoir, then an irrigated field and only after all these is there a sea. “The most recent survey indicates that the total

area under irrigation in Africa is about 13.4 million ha, of which almost 70 percent are located in five countries only (Egypt, Madagascar, Morocco, South Africa and Sudan) (Annex 2). The total area under irrigation in ten other large international river basins is about 7 million ha, which is just over half of the total area under irrigation in Africa (Table 2)." (10) Looking at these stats from the "Dams And Agriculture In Africa" published by Aquastat FAO, gives us a better picture for the sediments origins in Africa, and if we look at the MENA countries Egypt, Morocco and Sudan (which is a North African country, but not always included in MENA) we can trace the basins and their landscapes; the same applies to Madagascar and South Africa as both are semi-arid countries.

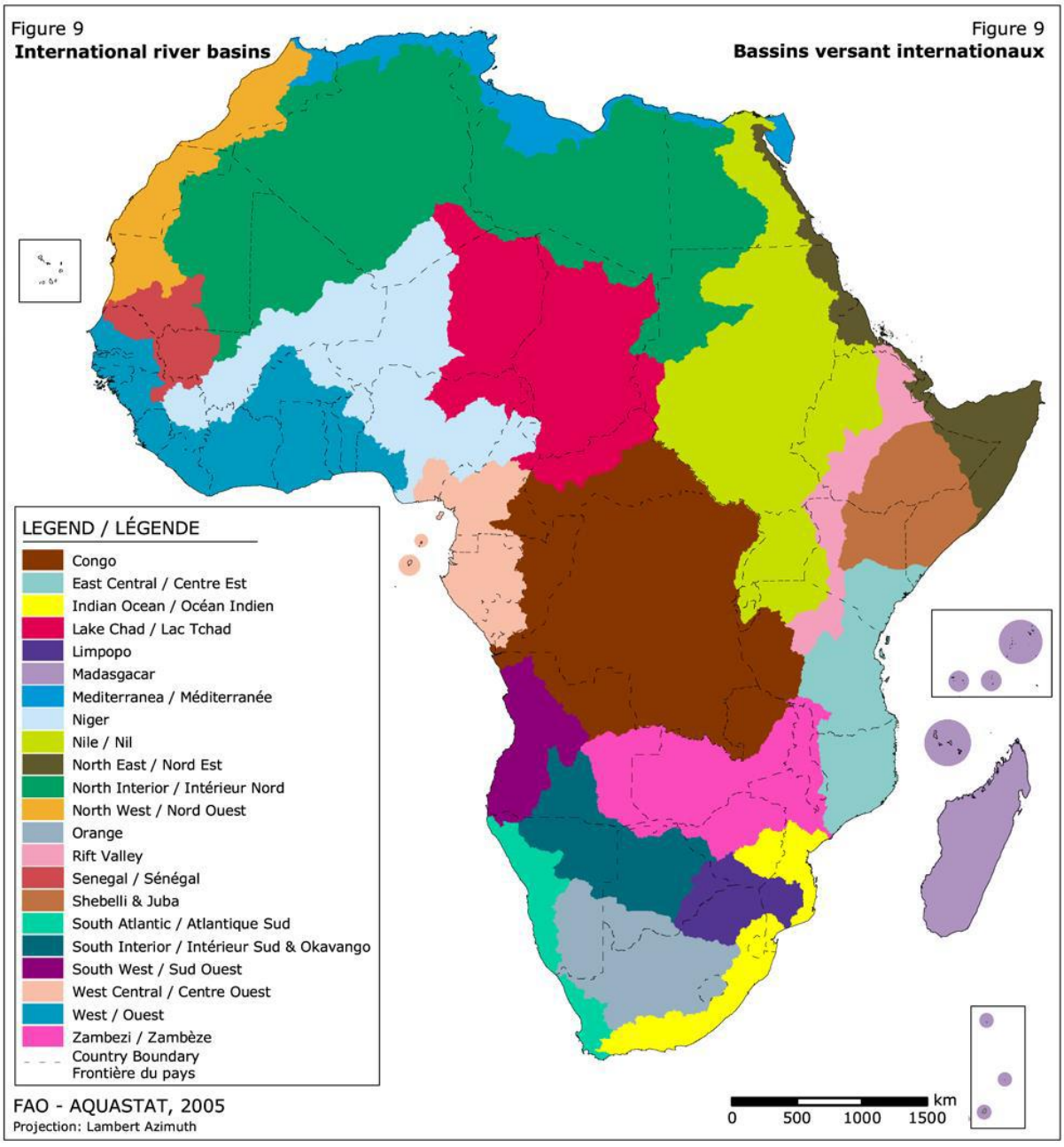

Figure 18. International River Basins of Africa FAO AQUASTAT (10)

The overall landscape geography plays a crucial role in sediment formation. For example, very steep Rocky Mountains with little to no vegetation and a river cutting through them will, once dammed, create a reservoir which will be sedimented faster than a reservoir filled with sediments from a river meandering through a flat lands or a valley covered with forest and shrubs. Both in North and South Africa we have the first case more dominant, Morocco is a mountainous country with harsh terrain and little vegetation, hence looking into its dams and the possible consequences of intensified climate change leans towards increased risk of rapid dam sedimentation "The projections of climate change trends over the next 20 years, according to IPCC methodology, predict for Morocco a general decrease of about 4 % annual precipitation, a 15 % decrease of surface water discharge and an increase in the frequency of extreme events (floods and droughts). In such conditions, the construction of more dams is likely to have serious environmental and related societal impacts on the coastal zone." (17) Even though these predictions instinctively make us think of dam construction for preserving the little water that will came in short outbursts in a form of flash floods, this is not a solution without taking into account the whole ecological landscape, and how it will be affected with the dam construction as well as with the intensification of flash floods. "Damming has increased over recent decades to better manage the water shortages in Morocco caused by recurrent droughts. However, the reservoirs have experienced siltation from the high rates of natural and accelerated erosion in the hinterland. The annual sedimentation rate in the main reservoirs averages 50 × 106 m^3 yr–1. This high siltation rate has serious environmental and socio-economic impacts, because it reduces the reservoir capacity and may be affecting the morphological equilibrium of the coastline," (17) As well as shortening the life span of existing reservoirs. In Morocco the Mohamed V reservoir will fill with sediment within 59 years "…having lost 35 % of its storage capacity between 1967 and 1991. It is estimated that by 2030, 70 000 ha of irrigated land and 300 MW of electricity will be lost as a consequence of the high rates of dam siltation." (17)

A similar situation is in Egypt where although the Nile Valley is flat and green, the Nile River passes through many highlands before reaching Egypt.

The Nile Basin and Aswan High Dam Reservoir Sedimentation

To better understand the Nile River and the Aswan High Dam Reservoir and its patterns and levels of sedimentation we will look at the overall Nile River Basin (Figure 19). The White Nile and the White Blue create the Nile River starting from Lake Victoria and the Ethiopian Highlands respectively. The Nile is the longest river in the world. "Many dams exist along the Nile River for various purposes. Noticeable was that, the sedimentation, within their reservoirs, reduce their capacity and their effective life span. The Sennar Dam was constructed on the Blue Nile (Sudan) for irrigation purposes. Due to the sediment deposition over a span of 61 years, the reservoir has lost 71 % of its original capacity. The Roseires Dam was constructed on the Blue Nile (Sudan) to store water for irrigation. It lost 36 % of its original capacity in a span of 28 years..." (28)

Figure 19. Nile River Basin

Nile Basin

The Nile Basin has eight major sub-basins that have been defined. They are Lake Victoria Sub-basin, Sudd Sub-basin, Bahr Al-Ghazal Sub-basin, Sobat Sub-basin, White Nile Sub-basin, Blue Nile Sub-basin, and the Atbara River Sub-basin.

In the Prof Dr Abdalla Abdelsalam Ahmed's book published by UNESCO in 2008, "Sediment in the Nile River System" describes the Nile basin saying: "The entire Nile Basin area is simply the sum of all the sub-basins mentioned above (2.1-2.7). Areas in which runoff are diverted to other river basins and arid areas where there is no rain at all are not counted, the entire Nile Basin corresponds to 1,527,500 km^2. However, in the literature the total area of the Nile Basin is estimated as 3,112,369 km2, Table (1), which includes areas without rainfall (i.e. has no runoff contribution to the Nile flow). The entire Nile catchment runoff/rainfall coefficient is estimated as 5.5 %, which is very small compared to other international rivers and even to the African ones (e.g. Congo Basin, Niger Basin). The average annual flow of the Nile is estimated to be 84 billion m^3 as measured at AHD. The latter figure (84 billion m^3) is the average flow of the Nile for the period (1905 – 1959). This value is the one on which the Nile Waters Agreement between Sudan and Egypt was based. However, the long term average flow of the Nile at Dongola gauging station is 73.0 billion m3 annually. The average flow at AHD reservoir is 70.0, billion m3 in the same period. The latter figure is supposed to cater for Egypt's share in the Nile waters according to the 1959 Agreement, i.e. with access of about 4.5 billion m3 in average annually for the last 45 years, considering the share of Egypt is 55.5 billion m3 and 10.0 billion m3 for evaporation annually from AHD reservoir." (29)

Country	Country total area (km2)	Country Area within the basin (km^2)	As % of total area of basin (%)	As % of country area (%)	Basin average annual rainfall in (mm)		
					Min.	Max.	Mean
Burundi	27834	13260	0.4	47.6	895	1570	1110
Rwanda	26340	19876	0.6	75.5	840	1935	1105
Tanzania	945090	84200	2.7	8.9	625	1630	1015
Kenya	580370	46229	1.5	8.0	505	1790	1260
Zaire	2344860	22143	0.7	0.9	875	1915	1245
Uganda	235880	231366	7.4	98.1	395	2060	1140
Ethiopia	1100010	365117	11.7	33.2	205	2010	1125
Eritrea	121890	24921	0.8	20.4	240	665	520
Sudan	2505810	1978506	63.6	79.0	0	1610	500
Egypt	1001450	326751	10.5	32.6	0	120	15
Nile Basin	8889534	3112369	100.0	35.0	0	2060	615

Figure 20: Areas and Rainfall by Country in the Nile Basin (29)

Here we see that of all the Nile Basin countries Egypt has the least amount of rainfall, followed by Sudan. As well as that Zaire, Uganda and Ethiopia contribute the most with average annual rainfall of over 1100mm. However due to different natural and manmade lakes not all the water ends up in the River Nile. In Figure 21 below it can be seen that the River Nile is mostly composed from waters coming from the Ethiopia and Blue Nile.

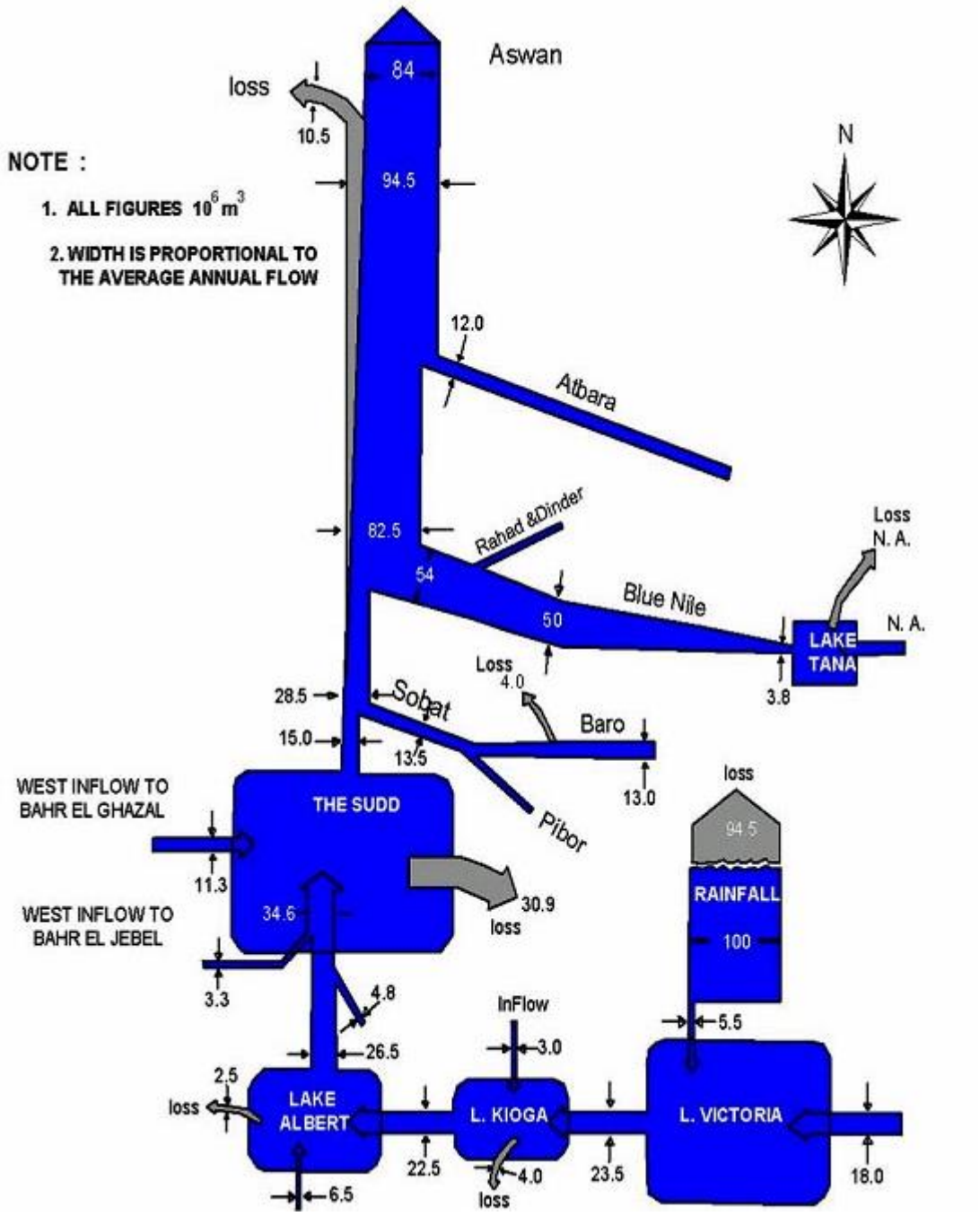

Figure 21. A Schematic Diagram of the Nile River Natural Flows - The Nile River Basin, the White Nile, Blue Nile and River Nile water distribution and their lakes and reservoirs. (29)

For example, the Sobat Sub-basin is made of The Sobat river that has two main tributaries: Baro river from the Ethiopian Highlands, and Pibor river from southern Sudan and northern Uganda. However, one of the main tributaries which join the Pibor River is Akobo river (originating from Ethiopian Highlands). Looking at all the reservoirs built on the Nile and its tributaries, we know that especially in dry regions sedimentation has serious implications on those reservoirs made for irrigation, potable water supply or hydropower. For irrigation and water supply loss in reservoir volume implies less stored water and hydropower generation interruption or curtailment. “Khashm El Girba dam reservoir in Sudan for example lost so far 50 % of its original capacity in less than 40 years with corresponding reduction in irrigation area. Roseires dam in Sudan generates a fraction of its hydropower potential during the rainy season because:

(i) Frequent blockage of the turbine intakes by sediment debris, and

(ii) "Low head available due to a minimum operation level maintained in the reservoir during the rainy season to reduce reservoir sedimentation." (29)

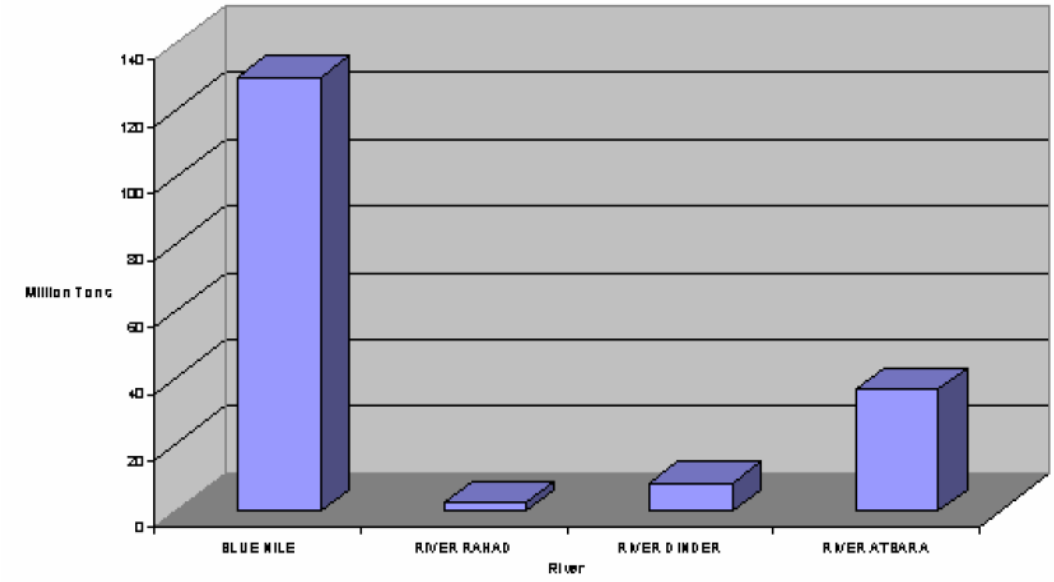

Figure 22. Sediment Load in Different Tributaries of the Nile River (29)

The construction of multiple dams on all the Nile River tributaries lowers the water flow but also the sediment inflow to the Aswan High Dam Reservoir. However, on the Figure 22 we can see that the lost sediment inflow is coming from the Blue Nile. This will be the case as well after the construction of the Grand Ethiopian Renaissance Dam. How much the sediment inflow will be lowered it is yet to be seen. For now we use what is available in the literature and this is "…the Nile River, … carried about 135 × 106 t yr–1 of sediment before construction of the Aswan High Dam (Stanley and Warne 1993). For millennia, annual floods provided Egypt with much-needed water to irrigate farmers" fields. The historic annual sediment input to the Nile River delta also helped offset geologic subsidence rates that range from < 1 mmyr–1 to > 4 mmyr–1 in the north-eastern delta region (Stanley and Warne 1993). Before completion of the High Aswan Dam in 1964, the Nile River delivered an annual average of ~84 km3 of water and ~124 × 106 tonnes of sediment to the coast, plus an additional 9.5 × 106 tonnes of suspended sediments deposited on the Nile floodplains. Subsequently, water reaching the coast has been reduced by 80 % and sediment loads by over 98 % (Stanley and Warne 1993, El-Sayed 1996). The only fresh sediment now reaching the coast comes via longshore transport and aeolian activity. As a consequence, erosion along parts of the shoreline has intensified and salinisation of cultivated land has increased. With 98 % of this sediment now trapped in the reservoirs, coastal erosion is intense – the Rosetta and Arietta promontories are eroding at the rates of 106 myr–1 and 10 myr–1." (17) By some authors the catchment of the AHD is greater than 98 % going to the full 100 %, as it was argued by Prof Dr Abdalla Abdelsalam Ahmed in his book: "It is clear that the peak of the sediment concentration in AHD reservoir falls within the period August-September, although the values are small due the fact that most of the sediment settled in the entrance of the reservoir inside Sudan. In other words, it can be concluded that the AHD has 100 % trap efficiency." (29) Meaning that all the sediment, which does reach the shores of Mediterranean Sea belong to bank erosion, as originally suggested in "Coastal Fluxes in the Anthropocene." (17)

As we will be exploring the Aswan High Dam Reservoir in depth, a short look at the history of the dam is useful: “In 1902, Egypt constructed the Old Aswan Dam on the Main Nile with a storage capacity of one billion m3. Several heightenings were implemented to increase the storage capacity to 5.0 billion m3 toward the sixties of the last century. Based on the 1959 Nile Waters Agreement between Sudan and Egypt, AHD was constructed to completely control the Nile waters for the benefit of the two countries. The AHD is a rock fill dam, completed in 1968 and fully operated in 1972. It is located 7.0 km south of Aswan City. AHD reservoir extends for 500 km along the Nile River and covers an area of 6,000 km2, of which two-thirds (known as Lake Nasser, 350 km) is in Egypt and one-third (called Lake Nubia, 150 km) is in Sudan... The long-term annual average (1929-1959) of sediment load that enters the Old Aswan reservoir at Wadi Halfa was estimated to be 134 million tons.” (29)

Origin of Nile Sediments
The usual Sedimentation Process unfolds in following stages:

- Erosion,
- Entrainment (drawing of particles into fluid),
- Transportation,
- Sedimentation/Compaction (deposition) (29)

These steps are part of the Nile Sediment formation, and in the figure below one can see the % of sediments in the Bukora Sub-Catchment by land use which are important to note, esp. forests 0,0 % degraded rangelands 67 %. This gives us an insight in erosion formation and an obvious correlation of lack thereof on healthy forests grounds.

Land-use type	Area (%)	Land use contribution and average export			
		Sediments			Runoff
		Cont	ER	Yield	Cont
		%	t/ha/yr	t/ha/yr	%
Degraded rangelands with patches of annuals	33.0	67.0	69.4	2.5	26.17
Perennials with patches of annuals	37.1	26.7	27.4	0.77	23.34
Grasslands	13.9	4.5	2.0	0.14	25.45
Forest	0.4	0.00	2.0	0.01	0.04
Woodland	15.6	1.8	7.4	0.17	25.0

Cont.: Contribution; ER: Soil loss rate; TP: Total Phosphorous TN: Total Nitrogen
Source: Majaliwa *et al.* (2004)

Figure 23. Bukora Sub-Catchment Land-Use Contributions (29)

The Nile sediments are mainly coming from the Ethiopian Highlands with high levels of dispersed sediment coming from eroded soils. “Nile tributaries originating from the Ethiopian plateau carry large quantities of sediment estimated at about 160-180 million tons annually. Most of this sediment is clay and silt carried in suspension during the rainy season. Dam reservoirs built on these tributaries are experiencing alarming loss in capacity due to sedimentation.” (29) This is a consequence of frequent alternating dry-wet seasons enhanced by agricultural over-use, overgrazing and deforestation to provide livelihoods and housing to local populations. These are resulting in increased deforestation and loss of topsoil hence supporting and accelerating water erosion of surrounding landscapes. “Therefore, it leads to land degradation in the upper land and

loss of reservoir's capacities, flooding, blockage of hydropower inlets, irrigation canal's sedimentation and water quality degradation. The latter collectively summarizes the negative impacts of soil erosion from the Ethiopian Highlands on the downstream countries, e.g. Sudan and Egypt. On the other hand, in the Equatorial Lake region, sediment results from soil erosion due to deforestation, human activities, and land use mismanagement. This leads to several negative impacts, e.g. threatening the overall biodiversity in the region in addition to the deterioration of the quality of water, especially in Lake Victoria. However, due to the swampy areas in the southern of Sudan besides, the several Lakes faced the White Nile through its way towards the north, most of the sediment deposits on those places. Hence the contribution of the White Nile to the Nile sediment discharge rate is less than 5 %." (29)

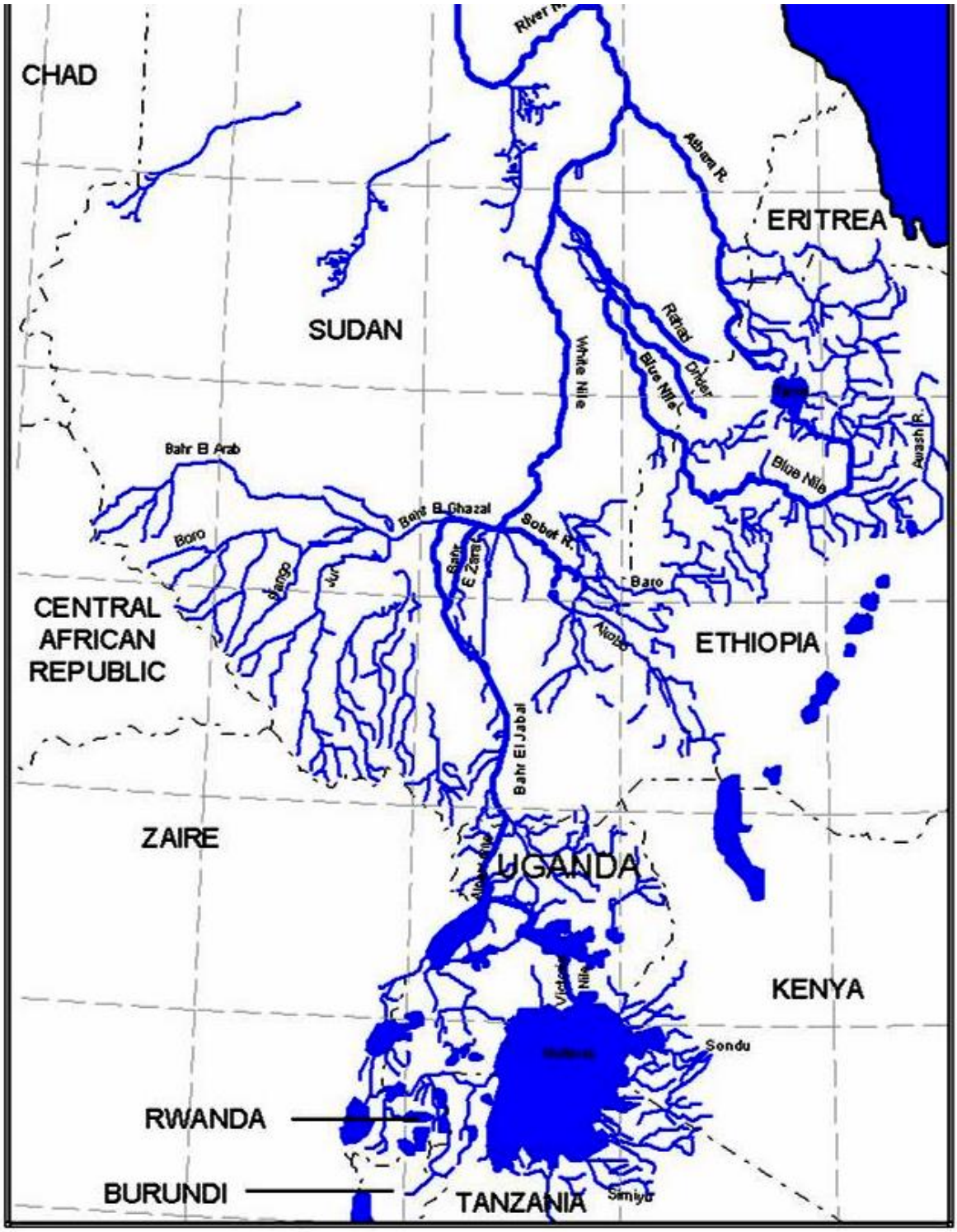

Figure 24. A further map of the Nile Headwaters. (29)

Looking at the whole Nile Basin, the Aswan High Dam Reservoir stands out as the largest manmade water body in the whole basin, and only the second largest in the World! "AHDR is the second largest man-made reservoir in the world. The reservoir extends from the southern part of Egypt to the northern part of Sudan. The AHDR has a total length of about 500 km (350 km inside Egypt and 150 km inside Sudan). The reservoir was created after the commission of the Aswan High Dam (1964–1968). The reservoir width depends on the water level; however, the average width of the reservoir is about 12 km. The water level varies between 152 and 182 m over the sea mean level. The AHDR storage capacity is 162 billion m3 distributed as follows:

- 90 BCM: live

- 31 BCM: dead storage.

- 41 BCM: storage for high flood waters between levels of 175 m and 182 m." (28)

Dead storage zone in reservoirs is predicted to store sediments and we calculate or try to predict the number of years for which the dead storage zone will serve us in this purpose, giving us approximately the life expectancy of the whole reservoir. However, when we look through literature on AHDR dead storage zone, it has always been described with so many inconsistencies that in one of the reviews authors compiled the table given in Figure 25, showing all the different dead storage zone predictions by years and authors.

Table 1 Useful life-related-pervious studies on Aswan High Aswan Dam Reservoir.

Author	Year	Conclusion
Russian Engineering [7]	Prior 1964	Dead zone 500 years
Ho-Khteef German Co. [7]	1970	Dead zone 750 years
American Building Authority [7]	1970	Dead zone1000 years
Abu EL-Atta [7]	1978	Dead zone 440 years
Shalash [3]	1980	Sedimentation 1570 million tons during 15 years period between (1964–1979); dead zone 362 years
Makary [8]	1982	Dead zone 408 year and total life 1580 years
Dahab [9]	1982	Dead zone 310 years
EL-Moattassem and Abdel-Aziz [4]	1988	Sediment 1650 million tons during 21 years period between (1964–1985)
El-Manadely [6]	1991	Sedimentation 2650 million tons during 24 years
Abdel-Aziz [10]	1997	Dead zone 311 years and live zone 1202 years
NRI [11]	2008	Estimated that more than 6.285 billion tons (1964–2008)

Figure 25. Previous life related studies on Aswan High Dam Reservoir (28)

Just how different are the views between different researchers on the Aswan High Dam Reservoir capacity and the life expectancy of the dam, may be attested by this passage from the "Sediment in the Nile River System" book from UNESCO: "However, almost all the sediment load reaching the AHD reservoir deposited in the live storage. A number of estimates of the potential life span of Lake Nasser located in Egypt and Sudan was published, ranging from 20 years to over 1500 years, Makary (1982). The time forecasted for filling the reservoir by sediment deposition is estimated by MWRI to be 362 years, which is less than the original design life span of 500 years. AHD as the second largest artificial lake in the world has its positive and negative impacts on the region and the socio-economic development of Egypt in particular." (29) As you can observe here, they adopt 362 years and that the live storage has been filling up, rather than dead storage. The present author is of a similar belief, that the live storage especially of the Sudanese part has been filling up accompanied with the bottom lake accumulation in the middle part of the reservoir or the dead zone, as this is very noticeable from the satellite images (Figure 26).

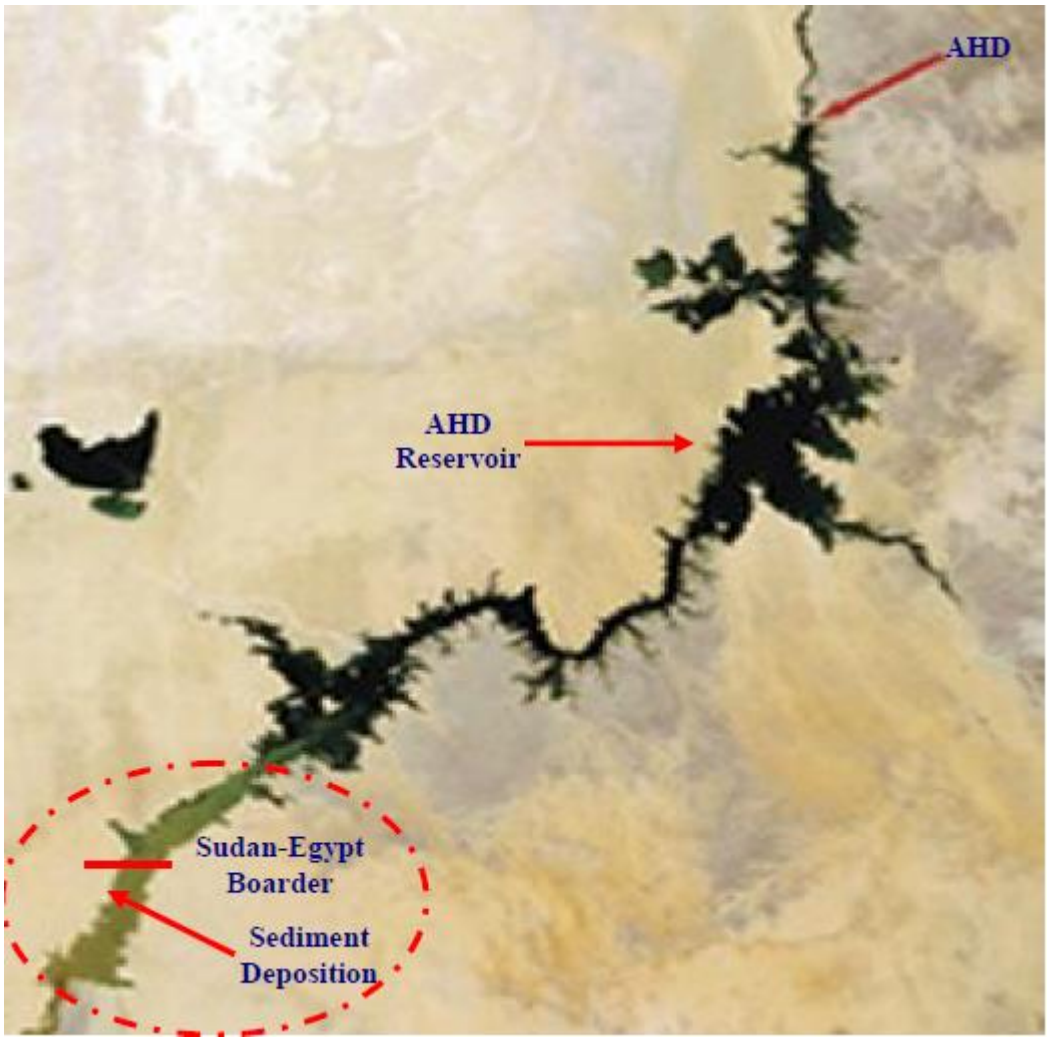

Figure 26. Nile sediments as seen from space (28)

What we can see from space, or satellite images, is that most of the sediment has been deposited in the Sudanese part "i.e. 82 % of the total sediment deposited in the Sudanese part and 18 % is deposited in the Egyptian part". (28) And that this part is indeed losing its live storage. In the figure below from the same book, we can see the measured values across the lake.

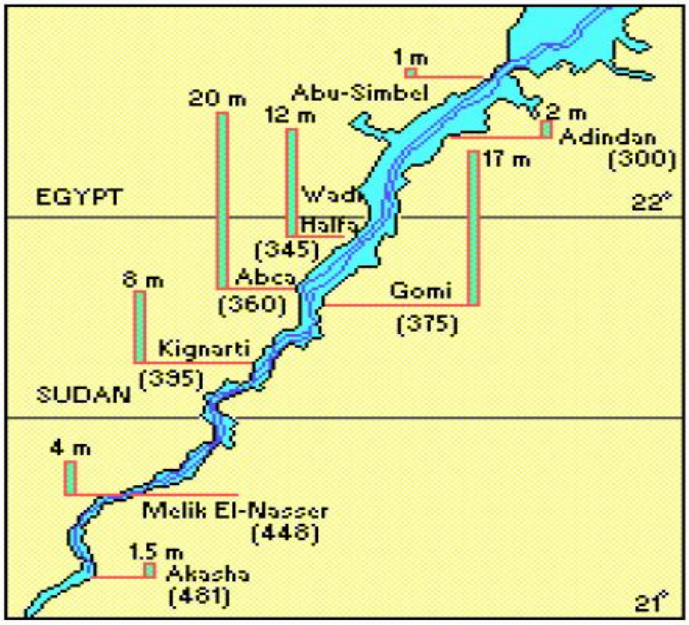

Figure 27. Distribution of the sedimentation depth in AHDR (29)

As for the Nile Sediment composition in the AHDR we know that: "The suspended sediment load in the Nile system is mainly distributed as 30 % clay (< 0.002 mm grain size diameter), 40 % silt (0.002 – 0.02 mm) and 30 % fine sand (0.02 – 0.2 mm)." (29) From the study on the Nile River sediments done by UNESCO we know that the most inflow of sediments into the AHDR happens between the months July and August, as represented in the figure below.

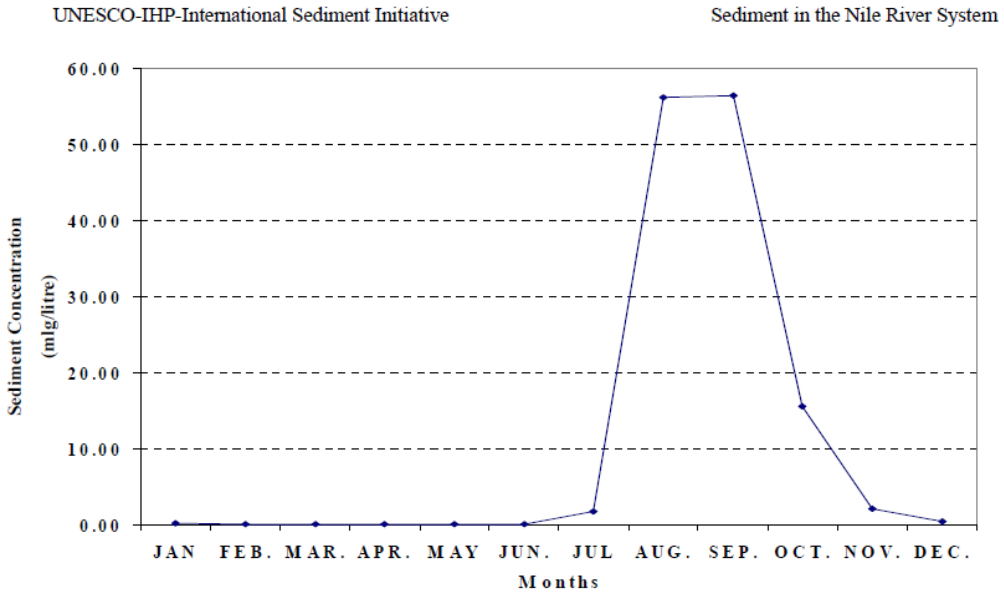

Figure 28. Suspended Sediment Concentration in AHDR (29)

The Egyptian Ministry of Water Resources and Irrigation (MWRI) carries out sediment analysis three times a year, before, during and after the flooding period.

“The measurements cover a distance of about 220 km up to the tail zone of the backwater curve (behind which no sedimentation is observed), Fig. (36). It can be noticed from the historical records that the sediment concentration decreases from 3000 ppm to just around 40 ppm, before and after AHD respectively. Fig. (37) and Plate (10) show the longitudinal profile and suspended sediment distribution along AHD reservoir. The total deposited sediment volume is estimated to be 2.5 billion m3 in the period 1964-1995. This reflects that the average rate of sediment deposition annually is 140 million m3 i.e. the rate of sedimentation is 0.1 %. It has been noticed that almost all the sediment deposition occurs in the Nile reach between 345 km and 430 km south of the dam site. In this region, sediment has already deposited in the live storage zone as shown in Fig. (38). However, several studies showed that until 1973, 99.98 % of sediment was deposited in Lake Nubia. Available data suggests that suspended sediment dominates the total sediment in transport, which account to approximately 90 % of the total sediment load. This means less than 10 % is left for the bed load. Table (9) gives a mean annual suspended sediment inflow over the period.

“1965/66 – 1977/78 as 103 million tons. If we assumed all the suspended sediment is deposited in the reservoir plus 10 % for the bed load (10 million tons), hence the expected life span of the AHD is over 1000 years. However, the dead storage requires about 200 years to be filled, but unfortunately most of the sediment if not all is deposited in the live storage, which slightly reduces the function of the dam.” (29)

Storage	From level (m)	To level (m)	Storage capacity billion m^3
Dead storage	85	147	31.6
Live storage	147	175	90.7
Flood control storage	175	182	39.7
Emergency flood control storage	182	183	7.0
			169

Figure 29. Storage capacity of the AHD Reservoir (29)

The shortage of sediments in the downstream areas of the river have many negative impacts as discussed in general at the beginning, and for AHDR specifically these are: “Although the Nile flows are well regulated downstream from the AHD, certain reaches of the Nile river are still prone to bank erosion (Osman et al, 2004). These are estimated to be about 12 % of the river course. Bank erosion is attributed mainly to erosion by induced flow shear, boat waves, free and seeping drainage water in addition to degradation.” (29) As well as the sardine production in the Mediterranean and salt water intrusion into delta and costal aquifers. These disadvantages have been documented throughout the literature, such as in the UNESCO book “Sediment in the Nile River System.”

Disadvantages

- The Nile delta is becoming smaller, because the Nile is no longer carrying any sediment downstream from the dam. The pebbles and sediment get stuck behind the dam. Wildlife is losing its home because the delta is shrinking in size.

– There has been accelerated desertification because farmers are abandoning fields with very low production.

– The rapid sedimentation near the head of the reservoir may dam up the narrow Nile valley in Nubia in a relatively short time. Therefore, the erosion increased along the lower Nile courses and the transgression of the Nile delta on the Mediterranean coast is taking place.

– Degradation of downstream river bank due to the clear water.

– Increase of groundwater table level causes rotting of crops" roots.

– High evaporation from the huge surface area of the reservoir."

And in Sudan for example "More than 60 % of the operation and maintenance (O&M) costs of the irrigation management in the Sudan irrigated schemes goes to sediment and aquatic weeds clearance, Plates (16,17)." (29)

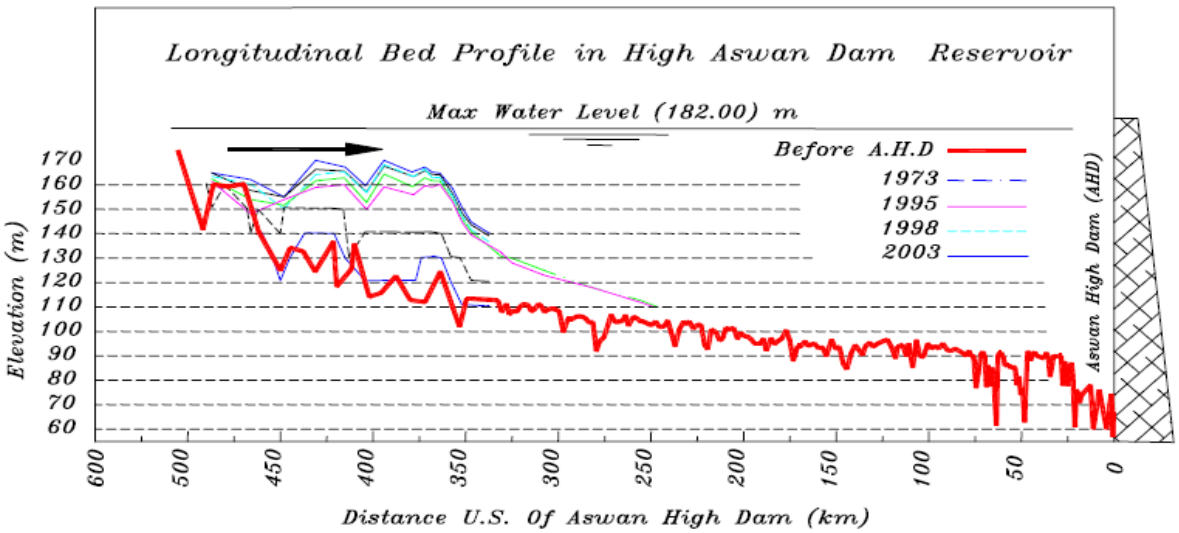

Figure 30. Longitudinal Bed Profile in AHD Reservoir (29)

The Aswan High Dam Reservoir suffers from persistent water quality degradation like non-oxygenation and/or thermal stratification. The main pollutant source can be found in agriculture, and the nearest source in Sudan. "With decreasing distance towards the High Dam body, the contaminant elements were diminished due to reduction in the environmental factors and Sudanese pollution sources leading to the northern Lake Nasser are considered to be less contaminated. Overall, the present study is an environmental alert for contaminated sediments that carried contaminants and considered the secondary source of pollution impact on ecosystem, and subsequently, their environmental risk on human health." (30) In an article published by Elsevier in 2013 titled "Geochemistry of the High Dam Lake sediments, south Egypt: implications for environmental significance" further conclusions on bottom lake sediment pollution and its origin, dispersity and grievances where determined: "The bottom sediments of High Dam Lake, south Egypt, stored huge amounts of water and sediments, both are affected by the Sudanese's industrial, agricultural, urbanisation and mining sewage systems causing remarkable pollution in the ecosystem. Lake Nubia sediments have been charged with high levels of most analysed elements which exceeded the Clarke values causing remarkable contamination. The contaminants Se, Cu, Ga, Pb, Ba, Rb and

Tl in Lake Nasser sediments were mostly related to Lake Nubia and in part to geogenic processes. The northern part of Lake Nasser sediments is remarkably affected by fewer pollution levels due to the far distance from Lake Nubia and geogenic activities. The contaminants were trapped in clays and/or organic matter of sediments and others were transported in refractory elements, additionally their dispersion controlled by the environmental variables such as distance, pH sediments and pH, EC and T of water.

"Consequently, the elements causing pollution could release from sediments to the ecosystem to be concentrated in aquatic plant and fish. There is a real need to conduct studies for the purpose of decreasing pollution and toxicity level in the High Dam Lake sediments that act as a carrier of contaminants and a source of feeding for aquatic plants and fish. Moreover, Tilapia nilotica and Tilapia galilea are considered the main source of fish in Egypt. The author recommended carrying out a survey of pollution activities, especially in Lake Nubia and around Lake Nasser to perform suitable remediation processes. Significant volumes of sediments should be removed away from the whole High Dam Lake for metal extraction, improvement of agricultural lands and industrial purposes. Cultivation of the aquatic weed plants near the Lake's shores is necessary to consume a large amount of trace elements and to decrease their toxicity level in the ecosystem." (30)

Agriculture has yet again displaced properties of a downward spiral, as the agricultural runoff at least in the Sudan and Egypt cases is creating additional problems, which are going back into the system, so perhaps changing the way agriculture is done today to a sustainable agroforestry system, would trickle down with multipliers in many unexpected places.

From this short overview on the current conditions of the Aswan High Dam Reservoir Sediments the following recommendations can be drawn upon for future researches:

1. Better data should be collected.
2. Better and cheaper data collection methods should be developed, especially for velocity distribution, wind speed and bed load.

"Different scenarios could be developed based on the future climate predictions for the region, and/or based on changes in sediment production and sediment delivery to the mainstream. It is clear that changes in the watershed and stream management upstream will have a profound impact on the discharge and the sediment load entering AHDR Watershed models, which link the sediment production and delivery in the upstream catchments to the sediment transport and deposition in the river channels and reservoirs, will allow us to predict the future behaviour of AHDR Future upstream engineering projects should be studied for its effects on the amount of water discharge and sediment deposition in the AHDR" (28)

Sediment Calculation Prediction Methods

There are different methods and tools to measure the sediment deposition within a lake. As mentioned before, they widely vary depending on the reservoir size, location and type such as on site or remote sensing. More attention to this was given in the UNESCO book on sediments that has been quoted frequently herein: "However all the developed empirical equations based on the above methods are either confined to the local watershed from where they had been developed or they give a rough estimation of the quantity of the sediment yield. Aerial photographs can be used to make qualitative, or with calibration, quantitative assessments of soil erosion rates. However, aerial photograph to assess soil erosion is subjective and has been superseded by other

methods. The most widely used empirical equation for the prediction of soil erosion is the Universal Soil Loss Equation (USLE), Wischmeier and Smith (1965), which estimates erosion rates by multiplying a number of factors, including rainfall intensity, soil erodability, slope length, ground cover and the presence (or absence) of soil conservation structures.

“Several empirical functions can predict sediment yields. These empirical functions are based on catchment area, slope, altitude, rainfall, runoff, temperature, plus factors indicating vegetation cover and proneness to erosion. Milliman and Syvitski (1992) successfully correlated sediment yields with catchment area and topographic factors using seven topographic categories. A number of methods are used in the Nile system catchments. One of the simple methods to predict the sediment yield (t/km2/yr) is through converting sedimentation rates to catchment sediment yield. In such a method sediment trap efficiency of the dam reservoir has been taken into consideration using Brune (1993) relationship (dam reservoir capacity / inflow). Moreover, proper density of the deposited sediment is necessary (usually 1.1 to 1.5 t/m3) depends on the deposits consolidations.” (29)

There are many studies performed on the safety and stability of the AHD and the possible impact it unfortunate breach could have on the downstream, and in the case of AHD downstream is the whole of Egypt. So it is not blown out of proportion to say that many people do fear the AHD caused earthquakes that may someday crack the dam. One of such possible scenarios is described in the following: “3- Scenario (3) was chosen to be simulated by 1D2D model because it represents the maximum inflow and normal water level of the Lake. This is considered the closest condition to reality. In the case of the Aswan High Dam failure, major damages can be expected along the Nile Valley. The resulting flood wave propagated down the Nile would cause the failure of all other dams by overtopping. The calculated flows were much larger than the discharge capacities of the main barrages except delta barrages. The wave travels down the Nile with a velocity that ranged between 0.5 and 4.5 m/s. The first propagation wave takes about 143 hrs to travel a distance of 953 km downstream the AHD. The total gross flooded area resulted for this scenario was about 13,466.10 km2. All of it was within the Nile Valley borders.” (31)

Dredging an engineering discipline dealing with removal of high sediments

Dredging is a process of removing any type of sediment obstructing a water way from a water body (harbour, delta, river, reservoir, lake or channel), transporting it, and depositing it, in a pre-determined fashion at another location far away. The usual dredged of materials range from sand to silt and clay, but dredging is used for multitude of other applications such as diamond dredging in South Africa. Generally, dredging is considered an expensive operation and a necessary means of recovering the navigational ability and the storage capacity of a water body, unless the deposits removed can be used for some beneficial purposes and reimburse for the operations.

We can find the origins of modern dredging across different cultures and especially marine oriented nations. The origins of modern day dredging and the marine engineering is a truly European legacy, with contributions from Italy, England, the Netherlands, Belgium, France, Spain, Germany and Sweden.

However, looking back in time from our excavations around ancient Egyptian harbours we can see that even then, there were some primitive forms of dredging in place. Ancient Egyptians used hand-drags to maintain their harbours, so did the other ancient Mediterranean civilizations (Greeks, Romans and Mesopotamians): “From hand-drag to

draghead: Once dredging meant a solitary person wielding a single instrument to clean a local river or canal. Today the enormous draghead of a jumbo trailing suction dredger, reaching many metres below sea level moving millions of cubic metres of sand, all over the world is the industry standard." (32)

"By the end of the 19th century, all basic technology, short of automation, that is used in modern-day dredging was already known. Out of individual and family businesses, new forms of companies would grow. In 1900, the framework of most of the dredging groups that exist now at the turn of the millennium became visible." (32) Many of the large dredging companies are still pretty much family owned businesses, not only in Europe but across the world. The largest dredging company in Bay Area California, Dutra Group is a family owned company. Below is the photo from their museum on dredging The Dutra Group Dredging Museum.

Figure 31. Author in The Dutra Dredging Museum California, USA with a model of scraper dredger exhibited.

"All dredging equipment used nowadays derives from three inventions of the 19th century: the steam engine which replaced human, horse or wind-driven engines, the centrifugal pump, and the rotating cutterhead." (32) Scrapers and clamshell dredgers are not so much found as everyday dredgers, as they were at the beginning of the 20th century.

Figure 32. Author in The Dutra Dredging Museum California, USA in a Vintage Clamshell Dredging Bucket, property of Dutra Group.

Archaeological excavations can attest to the great importance of dredging, especially harbour maintenance and keeping canals navigable. This is of course amplified today: “Maintenance dredging, obviously of the utmost economic importance, greatly improved in the 19th and 20th century – not only in terms of productivity but also with respect to efficiency and precision.” (32)

Since the beginning of the 19th century and the first wave of globalisation, keeping the waterways navigable was considered a priority. And so was the search for the new faster, cheaper and safer routes. In one of these quests, the monumental Suez Canal project was initiated. Actually, it was the start of the construction of Port Said: “Works included construction of Port Said, requiring the building of two 1.6-kilometre-long breakwaters, capital dredging of 1.8 million cubic metres of sand, and the reclamation of 118,000 square metres.” In the Dutra Group Museum is a book, a personal diary of a ship carpenter who witnessed some of the excavation works which took place in Suez Canal back in, 1876-1916. This is how Suez was described in an article titled “From Hand-drag to Jumbo: A Millennium of Dredging”: “In those days, Suez was but a small fishing village at the Red Sea shores where most of the people had never seen a tree or a flower in their life. There was no drinkable water, so water had to be brought in either from the so-called Wells of Moses at the gates of the then-Syrian desert or from Cairo where it was traded in goatskin sacks or purses. Even after a weekly ‘water train’ arrived in Suez from Cairo, one bottle of Nile water was said to cost as much as ten bottles of wine.” (32)

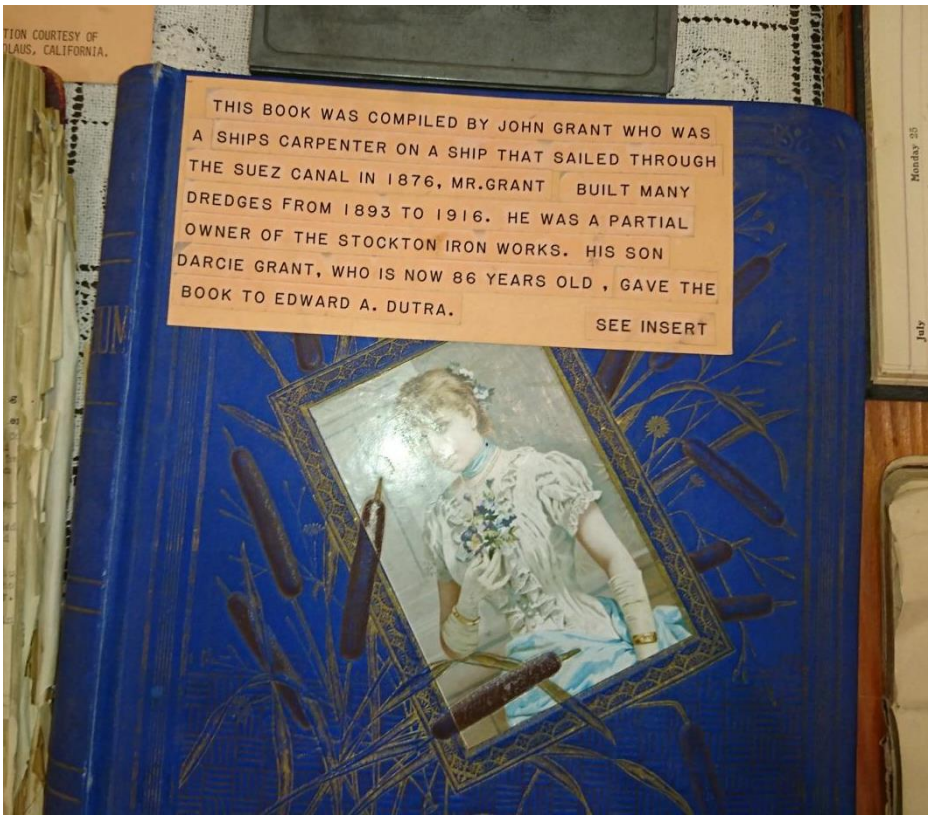

Figure 33. Author's photo of the exhibited personal diary of Mr John Grant; The Dutra Dredging Museum California, USA

Dredging was always characterised as capital work, which resulted in creation of new or improved facilities like harbour basins, deeper navigation channels, reservoirs and dam function maintenance. It has been used for preservation and continuation of navigational infrastructure, coastal engineering, the mining industry, and the offshore industry. Maintenance dredging as shown in Figure 34 below, plays an important role for navigation, land reclamation, flood management, clean up, drainage and water supply. And because modern day transportation cannot be imagined without perfectly functioning dredging systems all across the world, environmental impacts of dredging are very important part of their operation.

Environmental impacts

Short-term effects of the dredging activity:

- –suspended sediment leading to turbidity;
- –overflow from hoppers;
- –loss of dredged material during transport (hopper, pipeline);
- –smothering or loss of benthic fauna at placement site.

Decision-making on dredging needs a site-specific assessment to determine if there are unacceptable effects and if they can be sufficiently mitigated or compensated. Mitigation of potential environmental impacts: Improve accuracy–dredging thin layers and reduce dredging volume–improved on-board automation and monitoring; Reduce turbidity; Reduce spill, loss; Minimise dilution, increasing density." (33)

The definition of turbidity, which plays an important role in determining the environmental safety of the dredging operation, is explained as: "Turbidity is a description of how clear water is, or in other words, the degree to which water contains particles that cause cloudiness or backscattering and the extinction of light. Turbidity occurs naturally and high turbidity may be caused by a high content of fine sediments

and/or of organic particles, or by low concentrations of material with high light absorption. Suspended sediment concentration (TSS or Total Suspended Solids) is the measurement of the dry-weight mass of sedimentary material that is suspended in the water per unit volume of water. A more detailed description of turbidity is given in Chapter 5." (34)

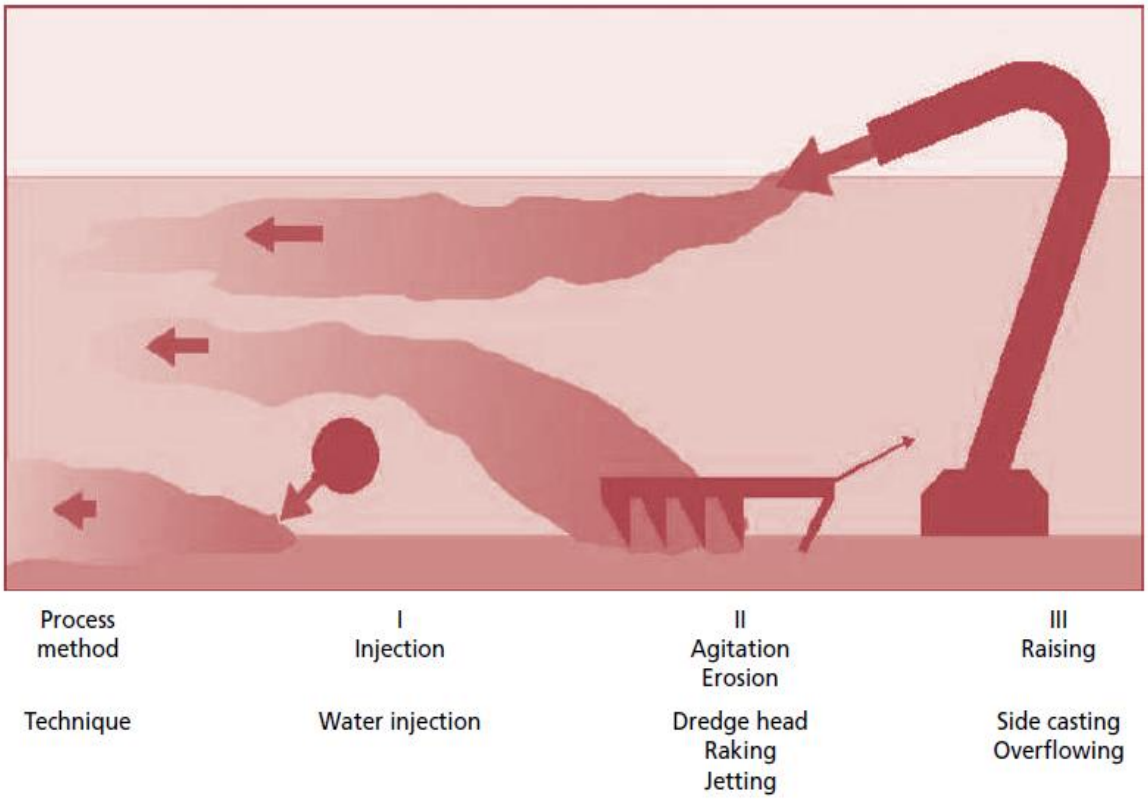

Figure 34. Hydrodynamic dredging processes (34)

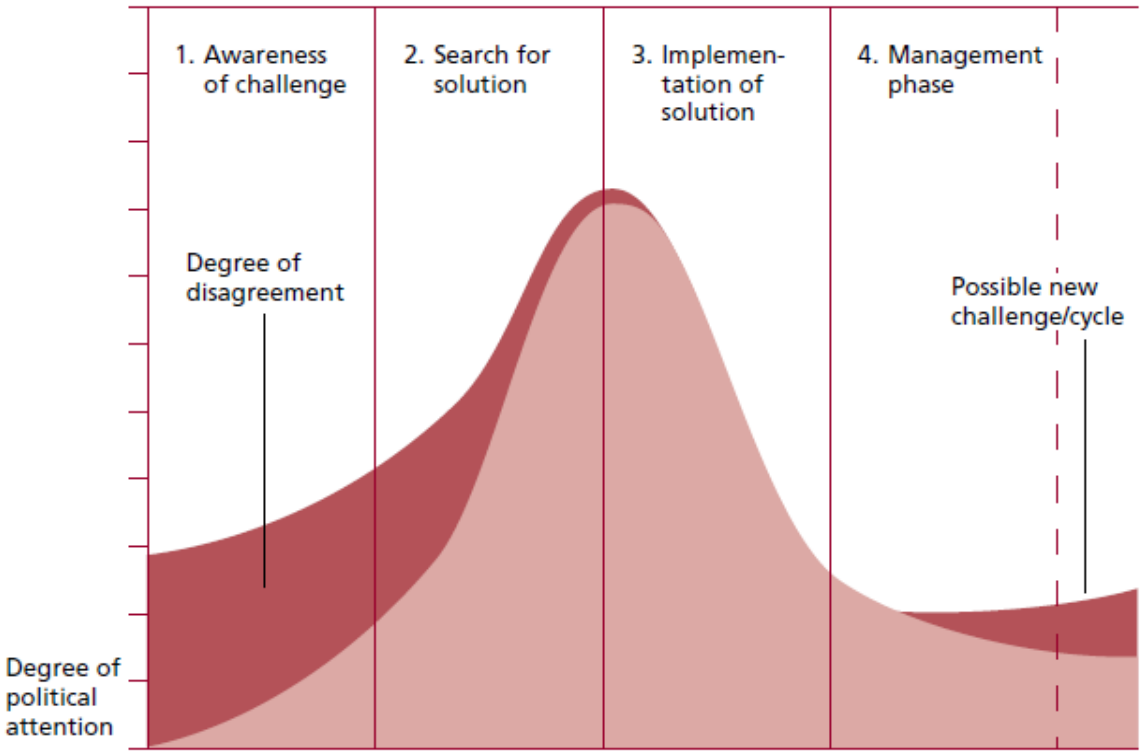

Figure 35. Life cycle of an environmental challenge in dredging operations (34)

Environmental Aspects of Dredging was written by Nick Brady and published by the Central Dredging Association (CEDA) and the International Association of Dredging Companies (IADC) a Triple Bottom Line. Included within is a methodology for the assessment of dredging technology and placement options for a major dredging project taking account of the environment is described as the following:

"The short-listed dredging technology options are compared for each dredging area using multi-criteria analysis. The multi-criteria analysis involves comparison of options against relevant environmental, social and economic criteria (the triple bottom line). Options are scored for each criterion on a scale of 1 to 10 with the highest value indicating highest suitability. The analysis is performed separately for dredging of uncontaminated and contaminated materials. The criteria address the key technical, operational and environmental factors that might influence the selection of the preferred dredging technology."

Placement options

The three options are compared using a multi-criteria analysis against the following criteria covering environmental, social and economic aspects, in a similar approach to that of dredge technology selection. Criteria are selected giving consideration to:

- relevant environmental, social and economic factors (including shipping safety)
- findings from the project risk management process
- assets, values and uses in the vicinity of the locations of the short-listed options
- indicative dredging schedule

To compare the alternatives, the three options are scored in relation to the identified criteria. To investigate the sensitivity of the outcome to different criteria weightings, three weighting approaches are used in the analysis as follows:

- Non-differentiated: each criterion is given equal weight.
- Balanced: each category (economic, social and environmental) has equal weight with weightings within categories assigned to reflect importance.
- Green: the environmental, social and economic categories are given weightings of 60 %, 25 % and 15 % respectively.” (34)

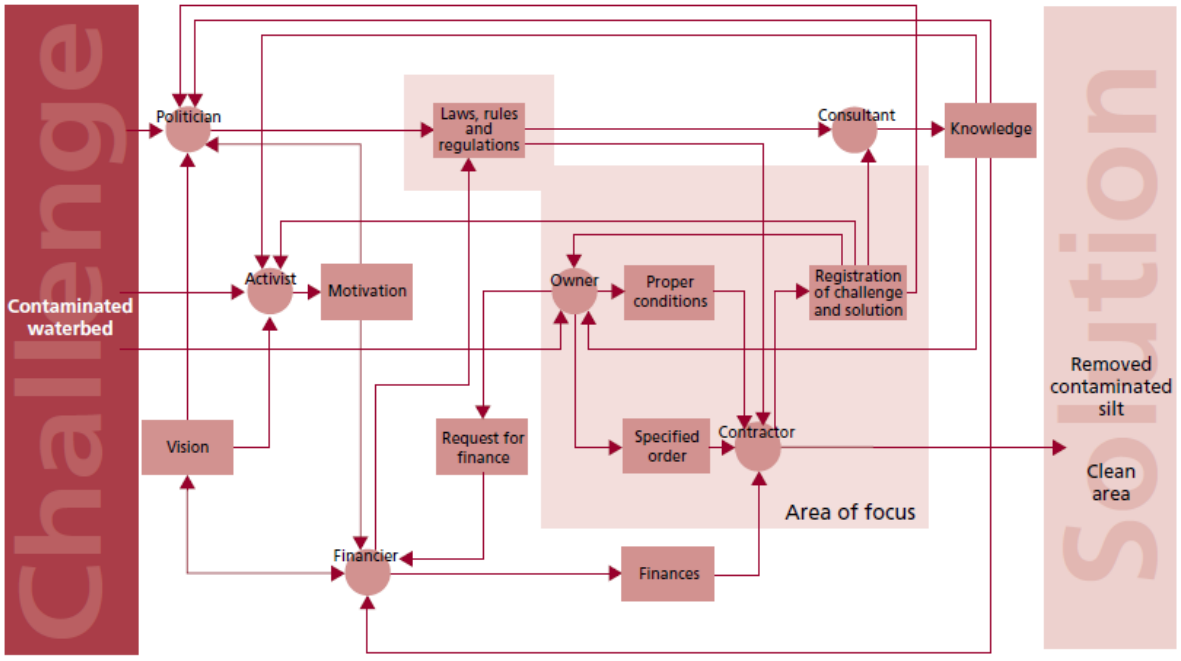

Figure 36. Multi criteria analysis for dredging in contaminated soils (34)

When looking into dredging activities from an environmental perspective, every dredging project consists of two inter-related elements; the Dredging Process and the Constructed Project. “The dredging process is generally short term and has a number of short-term effects, some of which may lead to long-term effects. The constructed project is the finished article, the culmination of a study, design, and construction and completion process. It is the part of the environment that has been intentionally altered by humans and which will most likely have long-term environmental effects, both positive and perhaps to some degree negative. All these effects in both the construction process and the constructed design are considered here.” (34) The study does take a very objective look into environmental consequences of dredging even though it was financed and published by the dredging industry. This may come as an odd outcome, but since the dredging industry has been suffering from a very bad environmental reputation for decades now it is actually a good change in industry models and a promising look at what the dredging industry can be in a few years.

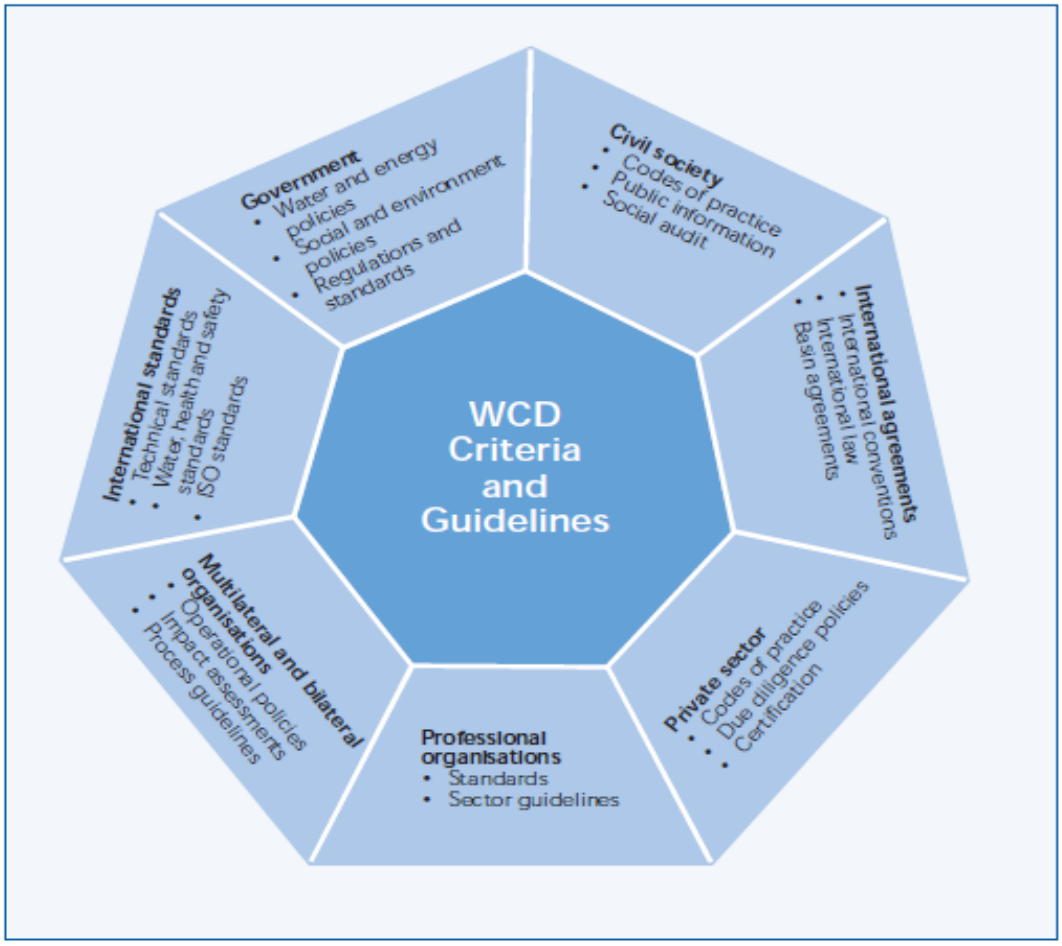

Figure 37. WCD Criteria and Guidelines

Different usages for dredged materials

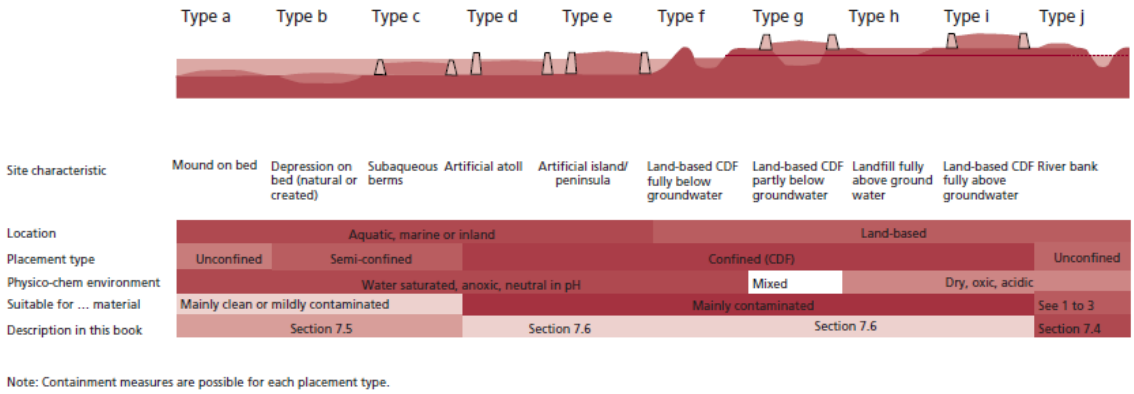

Figure 38. Dredged sediment placement options (34)

In Figure 38 we see the physical characteristic of the drop-off site for dredged materials. However, there are many other different possible uses of the dredged material and here the author will try to reflect on some of them through a literature review.

Let us start from the worst polluting industry in the world, the fossil fuel industry and their relation to dredging: “Dredgers have also proven to be effective means of cleaning up environmental disasters at sea such as oils spills. Both in the Prince William Sound, Alaska as well as in the Arabian Gulf off the shores of Saudi Arabia, dredging vessels

were called in to assist. Even more recently, dredgers have been used to sweep the sea bottom to collect debris after airplane accidents." (32) The dredged materials in this case are considered valuable goods, so it is operated with caution and not disposed of but rather processed.

The environmental impacts of mega dredging projects like Hong Kong harbours are vast undertakings which were and continue to be of major concern for environmental scientists: "Careful monitoring of impacts by the Hong Kong Government Environmental Protection Department was an essential part of the dredging operations. Remote sensing for turbidity by SPOT satellites, the Acoustic Doppler Current Profiler, Sidescan Sonar, Chirp Profiling and Profiling Siltmeter are some of the methods used for the measurement of suspended solids. Underwater ecological surveys by marine biologists who are qualified scuba divers were an additional expression of the will to protect valuable coral reefs." (32)

In the case of common sediment excavation and when sediments are not polluted a whole soil factory can be made, which was the case in Britain: "Soil factory-A full-scale soil factory was set up on a former quay on the River Clyde in Scotland which was capable of producing 2000 tonnes/week of topsoil. The material was supplied free by the Port Authority who had the benefit of reduced costs through not having to transport the material to the licensed placement site. It was used to regenerate redundant dock land for the Glasgow Garden Festival." (34) Usually originating from the high plains and being the actual alluvial soils" sediments, they can be classified technically as alluvium soil themselves, and in that case represent one of the top most nutrient rich soils in the world and supremely beneficial for agriculture: "When dredged material is free of nuisance weeds and has the proper balance of nutrients, it is no different from productive agricultural soils. Dredged material can alter the physical and chemical characteristics so that water and nutrients become more available for crop growth. In some cases, raising the elevation of the soil surface may improve surface drainage, reduce flooding and thereby lengthen the growing season. With saline dredged material, a conflict of interest arises in that drying is essential to successful handling, whereas washing with fresh water is required to reduce salinity. In the USA and in Belgium, bio-remediated dredged material is mixed with compost and treated municipal sewage sludge to produce "manufactured soil" for reuse in sanitation and landscaping projects. In Germany treated, dewatered dredged material is used for agricultural purposes in orchards. It has to fulfil special requirements to improve the soil and to meet specific quality standards." (34) Or equally for horticulture: "Horticulture crops are vegetable, fruit, nut and ornamental varieties of commercially grown plants. Dredged material applications on soils for vegetable production, orchards and nurseries are similar to those for agriculture. All commercially grown vegetable crops can be produced on dredged material amended soils. The best types are sandy silts or silty dredged material that can be incorporated into an existing sandy site.

Clays are too heavy for good vegetable production but could be improved by the addition of sand. Urban and suburban areas require large quantities of readily available grass for such uses as residential lawns, parks, golf courses and so on. Marginal soils near urban areas may be brought into turf production through applications of dredged material. Since grass is less exacting in its growth requirements than most food crops, the type of dredged material used is not as critical. The material should be a loamy or silty sand substrate to ensure the best growth." (34) The dredged material can be used in forestry: "The improvement of marginal timberland by the application of dredged material shows promise. Several rapid growing pulpwood species can be grown in dredged material. The same physical and chemical material properties discussed for

agriculture would apply to forestry, except that the trees could be grown safely on dredged material with higher contaminant levels. No documentation has been found of tolerance levels for heavy metals that may limit growth." (34)

There are many other uses of dredged material: "Beneficial use" is the term used by legislators to denote a use for dredged material other than placing it at a so-called "disposal site". The term implies that use of the material, rather than disposal, will be of benefit to the community. A number of examples may be found in the PIANC publication "Dredged Material as a Resource" (PIANC EnviCom, 2008a). However, most people do not define what exactly is meant by beneficial use, nor do they define who the beneficiary may be. In Chapter 7, "use" is defined as "any use which regards the material as a resource." Since there are now many examples of projects where dredged material has been used, even when it is classified as a waste, in this book the term "beneficial" has been dropped." (34)

Current look at the Terrestrial Carbon Dioxide Removal (CDR)

Using dredged materials as top soil or soil amendment, be it for agriculture or forestry or agroforestry or other land uses, brings us back to the core exploration of this thesis which is to use dredged materials as a kick starter for topsoil creation in the desert and a natural ecosystem booster for deserts" surroundings.

Here we will investigate mainly the best suitable options for transporting the dredged materials to the desired locations in the desert, the abundance of the silt itself as well as the best suitable option for utilising the sediments in the most sustainable manner so that they are not turned to dust immediately, under the Saharan sun.

For this we must first look into how do we make a quantum leap from soil amendment to forests? Perhaps the most important part here to note is a tendency of the author to focus on environmental sciences from very early age. The interest to use dredged material in topsoil creation in Sahara arose only because of its great promising attributes, building the Egyptian – The God of the Nile – and all the literate analogies that are used to describe the God of the Nile or silt (part of sediments) as something that had in fact saw ancient Egypt as the part of The Fertile Crescent.

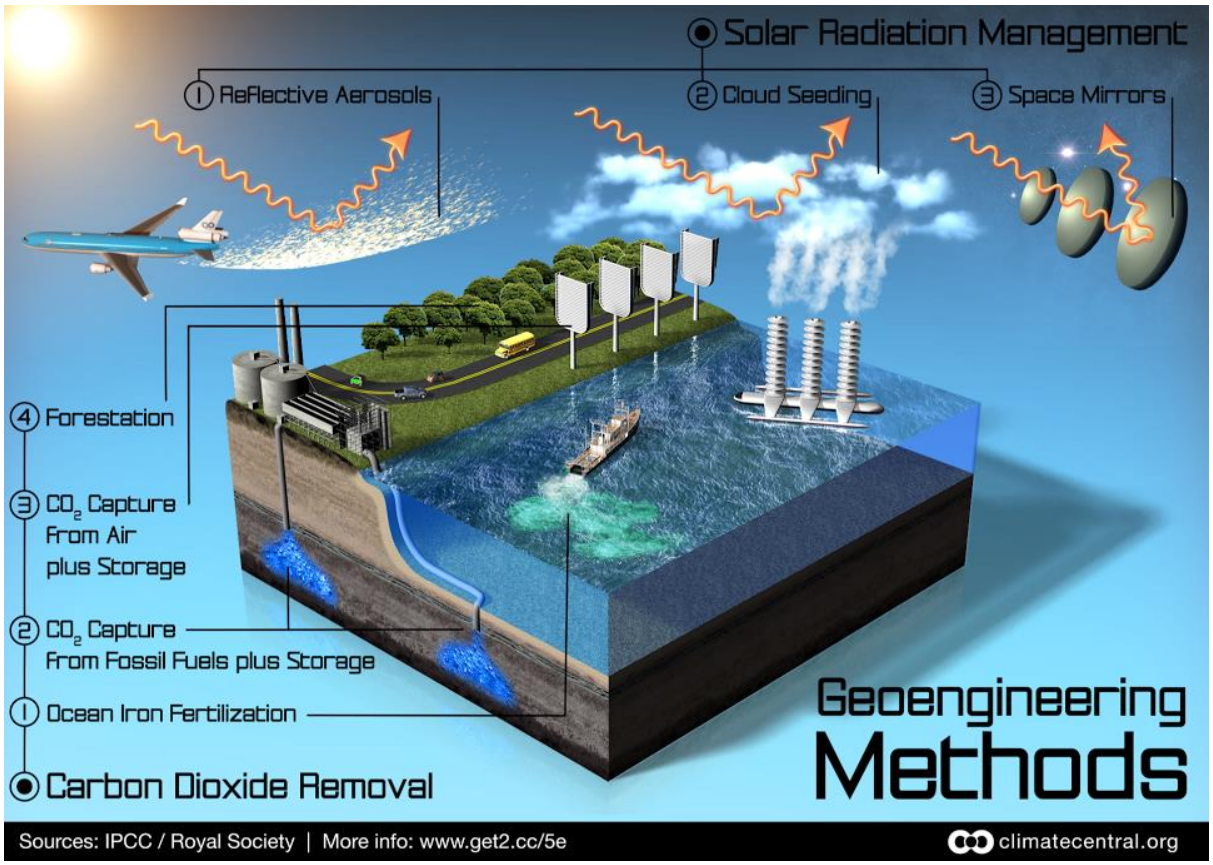

Figure 39. Solar radiation management

This thesis focuses on Afforestation as sub field of Geoengineering, a fairly new part of science which focuses solely on reversing the climate change and controlling the Earth's climate, as shown on in Figure 39 above. One of the best brief overviews on Geoengineering and all its sub fields or approaches was given by the Geoengineering department of the Oxford University's:

"Geoengineering is the deliberate large-scale intervention in the Earth's natural systems to counteract climate change."

There is wide range of proposed geoengineering techniques. Generally, these can be grouped into two categories:

Solar Radiation Management (SRM) or *Solar Geoengineering*

SRM techniques aim to reflect a small proportion of the Sun's energy back into space, counteracting the temperature rise caused by increased levels of greenhouse gases in the atmosphere which absorb energy and raise temperatures. Some proposed techniques include:

- ***Albedo enhancement***. Increasing the reflectiveness of clouds or the land surface so that more of the Sun's heat is reflected back into space.
- ***Space reflectors***. Blocking a small proportion of sunlight before it reaches the Earth.
- ***Stratospheric aerosols***. Introducing small, reflective particles into the upper atmosphere to reflect some sunlight before it reaches the surface of the Earth.

Carbon Dioxide Removal (CDR) or *Carbon Geoengineering*

CDR techniques aim to remove carbon dioxide from the atmosphere, directly countering the increased greenhouse effect and ocean acidification. These techniques would have to be implemented on a global scale to have a significant impact on carbon dioxide levels in the atmosphere. Some proposed techniques include:

- ***Afforestation***. Engaging in a global-scale tree planting effort.
- ***Biochar***. "Charring" biomass and burying it so that its carbon is locked up in the soil.
- ***Bio-energy with carbon capture and sequestration***. Growing biomass, burning it to create energy and capturing and sequestering the carbon dioxide created in the process.
- ***Ambient Air Capture***. Building large machines that can remove carbon dioxide directly from ambient air and store it elsewhere.
- ***Ocean Fertilisation***. Adding nutrients to the ocean in selected locations to increase primary production which draws down carbon dioxide from the atmosphere.
- ***Enhanced Weathering***. Exposing large quantities of minerals that will react with carbon dioxide in the atmosphere and storing the resulting compound in the ocean or soil.
- ***Ocean Alkalinity Enhancement***. Grinding up, dispersing, and dissolving rocks such as limestone, silicates, or calcium hydroxide in the ocean to increase its ability to store carbon and directly ameliorate ocean acidification." (35)

Different entities look into different characteristics for the same process in order to best describe the necessary measurements they know or suspect are important, but it is in essence always the same thing: what are we to do in order to reverse and/or cope with climate change? IPCC, the Intergovernmental Panel on Climate Change, would define it a bit differently, into adaptation and mitigation actions which we are to be taken in order to "deal" with climate change. "Along with adaptation, mitigation is one of the two central approaches in the international climate change process. Mitigation involves human interventions to reduce the emissions of greenhouse gases by sources or enhance their removal from the atmosphere by "sinks". A "sink" refers to forests, vegetation or soils that can reabsorb CO2." (36) Now knowing that forests and soils are considered essential regardless of the view point one might say, "great just plant forests." However, we first have to reflect on one of the greatest contributors to climate change to understand the importance and the role that the global forests are actually playing, and that is deforestation. "The current rates of deforestation, including tropical deforestation in South America, Africa and Asia, contribute to more than 20 % of human-caused greenhouse gas emissions, making deforestation across the globe a significant contributor to human-induced climate change." (36)

Hence just planting forests without taking adequate action to prevent deforestation will not contribute to reversal of climate change. In the same manner planting forests in a form of monoculture plantations in place of the virgin forests is nearly as bad as having massive concrete structures in its place. This is why it is very important to note the linkages between deforestation, agriculture, afforestation, reforestation and forest management, which will all be explored in depth further into the thesis.

Going back to IPCC and their observations and predictions on the state of our climate, with the current emission rates IPCC has published the following predictions: "According to the most stringent scenario of the IPCC, a long-term goal in line with the latest science would include:

- A peak in emissions in the next 10 - 15 years

- And a decline of 50 % over 2000 levels by 2050
- This would stabilise emissions at around 450 parts per million CO2 eq in the atmosphere and correspond to a 2 - 2.4°C rise in temperatures."

However here is where it gets a bit confusing. The stabilisation level is not defined and agreed upon yet at the United Nations Framework Convention on Climate Change UNFCCC: "The stabilisation level in the UNFCCC is not quantified. Discussions on future actions on climate change involve the question at what level stabilisation should be sought, and what constitutes "dangerous"." (36) For the author of this thesis, the science has always been fluid. This is one of the fundamental pillars of science, its ability to be disputed, challenged and changed once a better new definition or model appears. The way of expressing the current view on computer simulated models, empirically backed assumptions and theories, is science, therefore, still not defining the stabilisation level, can only be seen as a lack of both scientific and political will, persuasion, impotency and in some nuances, a legacy of overly bureaucratic Ancient Roman Empire systems of thinking. If we know that everything changes in science, as it does, and if we know we already hear daily of yet another species which went extinct thanks to manmade climate change and the Anthropocene we are living, isn't it now the upper limit? And then when and if we must or science proves us wrong, we just change the stabilisation level definition thanks to an abundance of new empirical data which will dispute the previous findings of Anthropocene or similar climate related and observable measurements.

However, for most of the terms UN has very clear definitions. This goes as well for CDR and on what can be considered an afforestation project and what can be considered a reforestation project. This definition was given in a short communication published by FAO UN: "Prior land use: Proof must be given that the land being utilised was not forested for at least 50 years ("afforestation") or was converted to other uses before 31.12.1989 ("reforestation"). Definitions: Under the CDM, "forests" consist of trees with at least a height of between 2-5 m, crown density between 10-30 %, and an area between 0.05-1 ha. Countries must choose values for these parameters and determine a minimum surface area of a "forest".

Since the Protocol does not define "tree"; fruit trees, bamboos, and palms may qualify. A&R can consist of assisted natural succession to trees, productive and protective plantations, agroforestry, and urban forests. For purposes of CDM, trees in a landscape may or may not reach the chosen threshold for crown density of a "forest", depending on crown cover and project boundaries. Enrichment planting in degraded forests or forest rehabilitation does not qualify as "reforestation". Additionally: Carbon sequestration via A&R must be additional to what would have occurred without the project. The Executive Board, a supervisory body for the CDM, applies a stringent additionally test to project proposals. A project is not additional, if it is the most financially attractive among feasible options. It may be additional if it overcomes barriers related to investments, technology or prevailing practice." (37)

With such clear definitions for what can be recognised as afforestation and what as a reforestation project, it becomes at least a bit confusing as to how they were not able to align around the stabilisation levels. In any case, as far as forests are concerned, the UN held the Durban Conference on the future of forests. From this conference and its proceedings, we can conclude that more and more emphasis is given to the crucial role which forests are about to play in mitigating climate change, providing the only resistant to enough sources of food manufacturing and carbon sinking which does not have the impending dooms day consequence looming as one of the outcomes. Surely we are realising that and it is becoming more common public knowledge that forests

especially agro forestry as a field will play a major role in humans successfully managing climate change and entering the 22nd century with no mayor population loses: “11 September 2015, Durban - The world’s forests must be recognised as “more than trees”, the XIV World Forestry Congress meeting in Durban, South Africa, concluded today. Instead, forests hold vast potential to play a decisive role in ending hunger, improving livelihoods and combating climate change.

The largest gathering on forests this decade set out its vision of how forests and forestry should look in 2050, adopting the Durban Declaration after a week of debate. The vision calls for the forests of the future to be “fundamental” for food security and improved livelihoods. Forests and trees must also be integrated with other land uses such as agriculture in order to address the causes of deforestation and conflict over land, according to the declaration. Finally, sustainably managed forests must be an “essential solution” to combating climate change, optimizing their ability to absorb and store carbon while also providing other environmental services.” (38)

Proceedings from Durban conference give an overview on the state of the global forests as well as what needs to be achieved in the near- and long-term future. Special concerns were raised on the increase of methane production and other greenhouse gases and possible alternatives. This was also an observable trend in articles which preceded the conference such as “The potential for land-based biological CO2 removal to lower future atmospheric CO2 concentration”: “Aside from the serious practical constraints of managing all global forests, and the biogeochemical and ecological implications of removing nutrients and habitats in rotting wood, the fact that anaerobic consumption of organic carbon can generate a flux of methane, which is 20–30-times more potent molecule-for-molecule than a greenhouse gas, does not appear to have been considered [21].

This is a well-known problem (or potential energy source) in landfill sites, but only less than 3 % of the carbon in solid wood buried in landfill is estimated to be converted to CH4 and CO2 in an approximately 1:1 ratio.” (5) This becomes an especially interesting observation for approaches such as hügelkultur, which will be explored in depth below, to be wider spread supported and adopted through regulatory bodies of UN, FAO and some of the others. This approach, developed in the Austrian Alps, aims to increase the forest cover, as well as the soil carbon content, which becomes even more important with today’s wide spread agriculture: “At this point, it is worth briefly considering the potential to also increase the organic carbon content of soil. This is already factored into studies of afforestation, but what about on cropland or other managed land? Switching from conventional tillage to no-till farming has been found to sequester carbon at shallow depths at a mean rate of 0.57 ± 0.14 MgC ha-1 yr-1 across 67 long-term experiments, giving rise to an increase in soil organic carbon storage of 7.1 ± 1.75 MgC ha-1, as a new equilibrium is reached within approximately 15 years.” (5) Although the article from T. Lenton is quite extensive in CDR comparisons and observation, one important question remains: did the study take into consideration that the CO2 emissions that will be caused by moving the carbon around which they plan to permanently dispose? Like of in the case of Biochar, as it becomes carbon positive when transported for more than 50km from the place it was made – with orthodox means of transport and unless the transportation is carbon neutral or negative.

The whole cycle of transportation basically from the first touch of sediments with the dredger to the last harvested produce is accounted for in this study. However as this was not made fully clear in the study, the conclusion was made: “Bioenergy CDR appears to have significantly greater potential than afforestation CDR, despite 50 % of the carbon being assumed to be lost as CO2. The main reason is that in the reviewed

studies, the productivity of short-rotation woody biomass energy crops is modelled to be far greater (~10 MgC ha-1 yr-1) [29] than the average yield of afforestation (~1 MgC ha-1 yr-1) [20]. This warrants further scrutiny, as does whether high yields of carbon can be removed from bioenergy ecosystems (and only partially returned as biochar), without reducing soil organic carbon storage. In our modelling, we have not calculated non-CO2 climatic effects. In particular, afforestation in the high latitudes can lead to net warming due to shading snow and lowering surface albedo and, if biochar is exposed on bare soil surfaces (e.g., after cropping), it may also lower surface albedo, causing warming." (5)

Afforestation, reforestation and Carbon Dioxide Removal were explained earlier. But throughout the literature one may encounter terms such as tCDR, BP, BECCS, CCS, AFOLU, ARP and CDM. tCDR refers to terrestrial carbon dioxide removal, which is very close to what was defined by Oxford University on CDR, but focused more on the use of vegetation. BP is an abbreviation used for biomass plantations, while BECCS is bioenergy with carbon capture and storage. Carbon capture and storage is commonly mentioned as CCS and UN uses AFOLU to describe agriculture, forestry and other land use, as a single term so that the carbon dioxide sequestration which happens does not get mixed or double counted within these multiple land uses. ARP/ARPs is an abbreviation commonly found to represent afforestation and reforestation projects piled together, and CDM famously stands as UNs abbreviation for Clean Development Mechanisms.

Knowing this we can go back to observable predictions for mean temperature rises, and their projections on when the tCDR could be the most effective: "Based on a moderate CO2 concentration pathway resulting in a global mean warming of 2.5°C above the pre-industrial level by the end of this century—similar to the Representative Concentration Pathway (RCP) 4.5—we assume tCDR to be implemented when a warming of 1.5 °C is reached in year 2038." Many recent studies and models show the importance of ARPs and BPs as a crucial part of the global mitigation actions: "Recent studies (Humpenöder et al 2014, 2015, Lomax et al 2015) see global re- and afforestation initiatives as well as managed BPs, combined with suitable conversion pathways (e.g. bioenergy with carbon capture and storage, BECCS), as an important component of the mitigation portfolio." This study concluded with: "If tCDR was implemented to counter additional emissions on a RCP8.5 trajectory, this potential would be insufficient despite our rather optimistic sequestration calculations. In view of limited space to reduce side-effects, tCDR can thus be considered as an ineffective CE tool to reverse carbon emissions. We show that we cannot bet on tCDR to supply negative emissions (Fuss et al 2014, Zickfeld and Herrington 2015) and that early mitigation, even with sustainably managed tCDR, is inevitable (Smith et al 2016)." (39)

To add to this not so birth projections is the observable fact of a majority of ARPs being misguided, mal managed and not executed with enough respect to the natural ecosystems where they are implemented, which all together further impedes the path of negative to neutral tCDRs. The best example for this is China: "Although afforestation is potentially an important approach for environmental restoration, current Chinese policy has not been tailored to local environmental conditions, leading to the use of inappropriate species and an overemphasis on tree and shrub planting, thereby compromising the ability to achieve environmental policy goals. China's huge investment to increase forest cover seems likely to exacerbate environmental degradation in environmentally fragile areas because it has ignored climate, pedological, hydrological, and landscape factors that would make a site unsuitable for afforestation. This has, in many cases, led to the deterioration of soil ecosystems and decreased vegetation cover, and has exacerbated water shortages. Large-scale and

long-term research is urgently needed to provide information that supports a more effective and flexible environmental restoration policy." (40)

From the policy perspective it is not only important to ensure the right guidelines in terms of the adequate locations for ARPs but also for accurate counting of CDR: "In the IPCC Fifth Assessment Report (AR5), for the first time, the vast majority of the terrestrial land surface, comprising agriculture, forestry and other land use (AFOLU), is considered together in a single chapter, though settlements (which are important, with urban areas forecasted to triple in size from 2000 global extent by 2030), are dealt with in Chapter 12. This approach ensures that all land-based mitigation options can be considered together; it minimizes the risk of double counting or inconsistent treatment (e.g., different assumptions about available land) between different land categories, and allows the consideration of systemic feedbacks between mitigation options related to the land surface." (41)

The acceptance in the political and policy maker circles is of utmost importance for the fast adaptation of these mitigation actions: "The Congress also saw the launch of an international five-year forests and water action plan to recognise the role of trees and forests in maintaining the water cycle, and to ensure appropriate management of one of the world's largest sources of freshwater." (42)

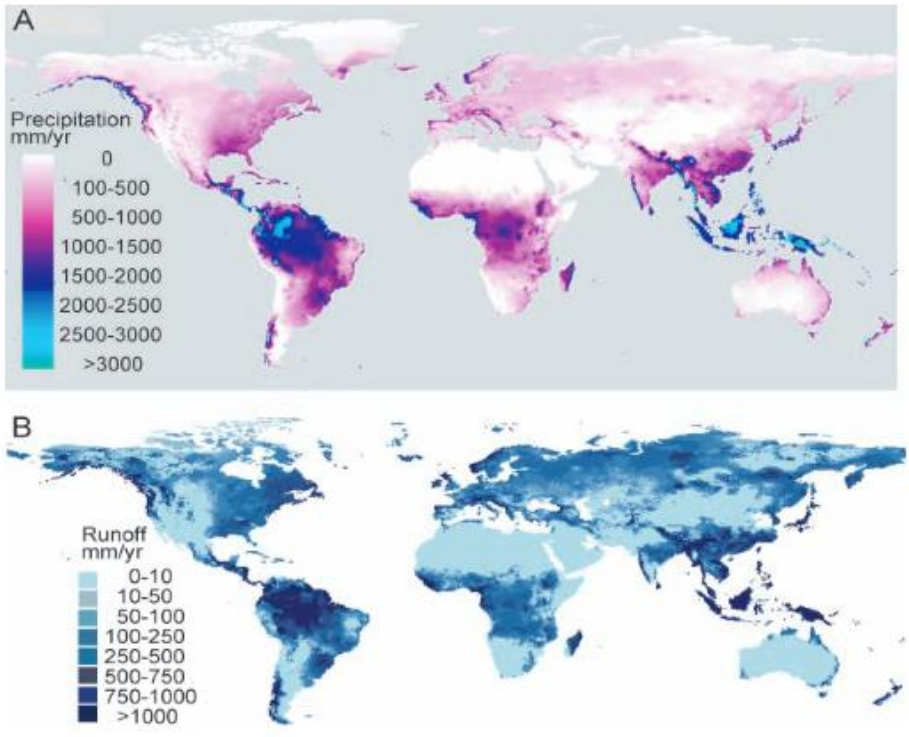

Fig. 2.6. Water flux. **a** Global precipitation (mm yr^{-1}) (Syvitski et al. 2003). **b** Hydrological runoff (mm yr^{-1}) after accounting for all forms of evapo-transpiration and human-induced consumption. The hydrological runoff divided by the drainage area equals the water discharge (km^3 yr^{-1}) (*http://www.bafg.de/grdc.htm*).

Figure 40. World hydrology map (17)

Looking at these grim water precipitation maps for the 21st century, one cannot but reflect on the idea that the only real promise of secure water is in planting forests: "A recent estimate of the "physical potential" of harvested plantations is that they could store up to approximately 900 PgC by 2100 (on 3.8–4 Gha) after an initial net emission of approximately 200 PgC in establishing them." (5) And if the zoning or use of too much possible space for development is of concern to local authorities, "if only allowing afforestation on abandoned agricultural land, the "social potential" for carbon storage

is reduced to 68–133 PgC by 2100 (on 695–1014 Mha)." And this is only for predictions calculated up to 2100: "Existing studies do not continue beyond 2100, but approximately 300 PgC would seem conceivable in the long term. Thus, it seems feasible that all the carbon that has been emitted by human land use change activities in the past could, in the long-term future, be recaptured by permanent afforestation." (5)

The last but certainly not the least important is the way of how we are financing these massive, literally Earth transformation projects and what are the most noticeable schemes now: "Our observations have slightly simplified the problem. Afforestation of subtropical deserts can reduce increases in atmospheric CO2, incrementally, and enormously. However, it can begin to show an operating-cost bonus (over CCS operating costs) of biogeophysically-induced rainfall, only after monumental capital investment in a major portion of the required desalination, power and irrigation infrastructure. These capital costs of mitigation will be borne mainly by the citizens of the developed world. They must be weighed, not only against those of CCS, but as a kind of pre-emptive disaster relief – or repair of the "commons"—to avoid the future, and as yet not easily estimated costs of vast coastal inundations, desertification of crop- and range-lands, drying up of water supplies; more intense tropical storms; the acidification of the oceans and loss of biodiversity. The integrated costs of coping with such changes could approach those of recovery following an asteroid impact or a nuclear war." (43)

We know that today the only real large-scale scheme in Africa is the Gezira-Managil scheme in Sudan: "…with an area of about 870 000 ha, which is irrigated with water from the Blue Nile through the Sennar Dam. Several schemes of more than 100 000 ha exist in Egypt, Morocco and Sudan. Schemes of around 50 000 ha exist in Algeria, Egypt, Mali, Morocco, Sudan and Tunisia." (10) When looking more closely to Egypt and its irrigation schemes as well as the potential for large scale irrigation projects, a chapter from Dr Prof El-Kateb from the Munich Faculty of Forestry and one of the direct advisers to Egyptian president El-Sisi speaks volumes: "Egypt currently allocates 6.7 billion m3 of sewage water annually. 5.5 billion m3 of this sewage water is sufficient to afforest over 650,000 hectares of desert lands and store over 25 million tons of CO2 annually in the new plantation forests" (El Kateb and Mosandl, 2012).

"Large-scale afforestation may stimulate cloud formation and may result in rainfall that the country urgently needs to expand its agricultural production areas (El Kateb and Mosandl, 2012). Their conclusion is supported by a press release of the University of Hohenheim (2012) and a recent study from Becker et al (2013). Becker et al (2013) suggest large-scale plantations of Jatropha curcas in hot, dry coastal areas to capture carbon dioxide from the atmosphere. The authors had conducted high-resolution simulations using an advanced land-surface atmosphere model and concluded that large-scale plantations of Jatropha curcas (10,000 km2) could lead to a reduction in mean surface temperature and an onset or increase in rain and dew fall at a regional level. To ensure sustainability, ecological and the economic success of large-scale afforestation, emphasis should be on the Political-Scientific-Economic Collaboration. This is achieved by a viable framework and optimal planning through the political, economic, and scientific environment, respectively, and by gathering the competences, experiences, possibilities and prospects of all the three spheres." (44)

In neighbouring Sudan we have a working business model for the state financed large scale irrigation schemes, which work in the following manner. Adopting business models as in surrounding countries like Sudan can be an option for Egypt. The interesting economic forces behind the rapid agricultural growth in Sudan, is the Business Model of State Provided Irrigation Sudan: "In the first method, which is called the combined

account (CA), the government of Sudan, the agricultural company and, the farmers share the net benefit from the sale of cotton in ratios of 40:20:40 respectively. The government takes the 40 % from the net revenue of the cotton production in return for providing land and water to the farmers. The agricultural company takes 20 % as management expenses and the remaining 40 % goes to the farmers. The net revenue is calculated after deducting the total cost of production in all farms from the revenue of cotton sale. No other charge is taken from the farmers for the other main grown crops i.e. wheat, groundnuts and, sorghum. However, the farmers are obliged to follow a strict cropping pattern in which a certain area of cotton has to be cultivated every year." (29)

Then we have the more promoted western model of ARPs financing: "In order to create incentives for the implementation of ARPs, demand for these projects should be enhanced. Assuming that reduction in costs may represent lower incomes for landowners in marginal areas, the main strategies to enhance ARP implementation should aim for negotiation of higher carbon payments, investment in high quality baselines to enable landowners to participate and reduce transaction costs. We consider that up-front carbon payments to landowners and lower transaction costs in the voluntary market generate more plausible conditions for the development of ARP in marginal rural areas than the current CDM scheme. Agroforestry practices which do not require full land use conversion (e.g. living fences) can be particularly useful and should play a larger role in the efforts to mitigate climate change." (45)

With this knowledge let us dig deeper into the matter and subject of this thesis, Making the Sahara Desert Green-via sustainable pipeline transportation systems.

Introduction to Dams

Dams are made by humans, nature or wild life, such as beavers. They represent an (impermeable) obstacle able to hold water which in time makes a stagnant body of water, a lake or in a manmade case a reservoir. Natural dams are made from landslides, earthquakes, volcanic eruptions or other causes such as the glaciers gliding down from mountain tops. That is how some of the most beautiful lakes in the world were formed, by glaciers melting down. These lakes were created after the last ice age, while glaciers glided down carrying with them lots of sediments or boulders that were once faced with an obstacle, such as a hill or a suitable valley not letting the glacier to pass and in lower altitudes formed a lake. Then there are also beavers. They tend to make dams so that they could be well hidden from predators and well-fed during wintertime. These dams are proven to be beneficial for improving the biodiversity, or when restoring wetlands, in preserving the frog population during winter, for cleaning downstream water of pesticides and so on. The last are the human dams.

The first of the manmade dams were found in the Middle East. This thesis will focus on them, their life span and explores the hidden potential they may hold in reversing climate change.

The History of the Dams

The first dams

Since ancient times, people around the world have searched for ways to tame Mother Nature. One of the first steps towards this goal involved "technological advancements" – including the taming and utilisation of fire prior to our ancestors evolving into modern humans. Our topic more concerns the emergence of farming hundreds of thousands of

years later. After the initial development period, many peoples came across their first impediment, which was the lack of constant water resources.

The first of the manmade dams[2] emerged in the Middle East. The assumptions on why they had developed there in the first place can partly be answered through archaeology today. Most of the researchers in this field agree on theories that revolve around man's first attempts at permanent settlements and/or developing agriculture. When these assumptions are overplayed with the Palaeocene geography of the Fertile Crescent and the general area of Sahara, a more prominent thought emerges on the first ancient settlements. Namely during this initial settlement period the local climate was different and they were able to be scattered around the desert, but as they clear cut trees and used them for housing and so on, with local climate getting dryer, water was become increasingly important and with it the ways to safely store and manage it.

History teaches us that ever since the beginning of agriculture; ancient people had developed different ways of how to control and use nature to for the advancement. One of their first steps towards achieving this can be observed in the early beginnings of farming. At the dawn of agriculture, we notice some of the first permanent human settlements, where water was available, with forests to clean cut as well, for housing, defence and new agricultural fields. However, as the time progressed and the streams dried over summer, with trading routes now established, or even nicer imperial palaces under construction, they were needed to secure permanent water supply. After a few generations living in the newly formed village, there came a time when they didn't want to move in order to have everything. They wanted to find a solution which would allow them to stay on forever.

And although forever never came, this connection between the first beginnings of farming and the need for drinking water and irrigation are inseparably interlinked with the first development of dams.

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[2] The word "dam" and its Anglo Germanic origins

If we look for the origins of the word "dam" in the English language, it can be traced back to Middle English and even before that to Middle Dutch (169). Numerous Dutch cities have the word "dam" in their name, like Amsterdam, Rotterdam, Volendam, Mannickedam and others, which is no wonder since they are a submerged country. As one of the capital cities of Netherlands, Amsterdam was founded around 1250 with the building of the dam that gave it its name "Aeme Stelle Redamme" which in Medieval Dutch stands for: "Dam in a Watery Area". This was one of the first cities to be built around the dam. From a small medieval village Amsterdam grew into an important harbour and port by the end of the 16th century. However, the first dams can be found much earlier in our history and the word "dam" itself is only linked to Anglo-Germanic languages.

Figure 41. The Modern day Turkey, Tigris river ancient dam

Going deeper into the subject of connection and correlation between the early agricultural practices, early civilizations and dams, it can be observed that after the hunter gatherer phase, people began to settle down, started to farm and developed civilizations. The Neolithic Revolution marked the beginning of the agriculture civilizations and the rise of technological progress. The Neolithic Revolution happened some 10 000 years BCE conquering the Fertile Crescent and the Indian subcontinent. This period is aligned with the end of the last ice-age, the Pleistocene Epoch, which began about 1.8 (2.58 (46)) million years ago and lasted until about 11 700 years ago circa 10 000 BCE. The lush greenery that was then the Sahara Desert supported the development of the first civilisations and with them the first crops and cattle domestication. Slowly through a period of several thousand years, the area turned back into desert. In fast forward history class, people came across their first impediment, which was the lack of constant water resources. The development of the ancient civilisations in the Saharan region is well persevered and documented partly due to the dry climate, and partly to the appetite for construction the ancients exhibited.

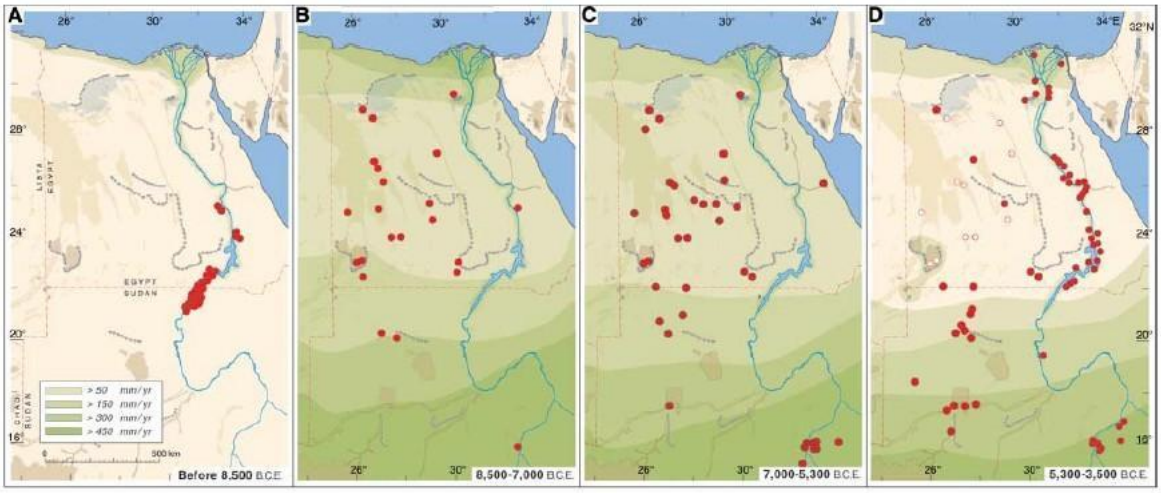

Fig. 3. Climate-controlled occupation in the Eastern Sahara during the main phases of the Holocene. Red dots indicate major occupation areas; white dots indicate isolated settlements in ecological refuges and episodic transhumance. Rainfall zones are delimited by best estimate isohyets on the basis of geological, archaeozoological, and archaeobotanical data. **(A)** During the Last Glacial Maximum and the terminal Pleistocene (20,000 to 8500 B.C.E.), the Saharan desert was void of any settlement outside of the Nile valley and extended about 400 km farther south than it does today. **(B)** With the abrupt arrival of monsoon rains at 8500 B.C.E., the hyper-arid desert was replaced by savannah-like environments and swiftly inhabited by prehistoric settlers. During the early Holocene humid optimum, the southern Sahara and the Nile valley apparently were too moist and hazardous for appreciable human occupation. **(C)** After 7000 B.C.E., human settlement became well established all over the Eastern Sahara, fostering the development of cattle pastoralism. **(D)** Retreating monsoonal rains caused the onset of desiccation of the Egyptian Sahara at 5300 B.C.E. Prehistoric populations were forced to the Nile valley or ecological refuges and forced to exodus into the Sudanese Sahara where rainfall and surface water were still sufficient. The return of full desert conditions all over Egypt at about 3500 B.C.E. coincided with the initial stages of pharaonic civilization in the Nile valley.

Figure 42. Climate-controlled occupation in the Eastern Sahara during the main phases of the Holocene (Rudolph Kuper and Stefan Kropelin [2006] Climate-Controlled Holocene Occupation in the Sahara: Motor of Africa's Evolution. 313 Science www.sciencemag.org).

The majority of grand civilizations developed in the MENA region and the Indian subcontinent, mainly around big rivers like the Nile, the Ganges, the Brahmaputra, the Tigris and the Euphrates, so it is no wonder that they were the first to come up with the idea of constructing a dam. The rivers were more unpredictable than they are now, with uncontrolled floods and not so rare drought years which left ancients with a meaningful puzzle: how to control the mighty power of "the river gods:" how to create conditions which would allow them to stay.

This explains why some of the first dams where mostly gravity dams made to collect the rain water and redirect it through irrigation canals for agricultural use, or diversion dams made to divert the excess flood waters, which could later be used in irrigation purposes too. Later on, dams were also used as mills for cereal like barley and wheat (especially smaller dams) or for gathering the rain water from hilly streams into artificial underground impounds or aquifers, transporting it to desired location by quants with minimum to no evaporation along the way. We can draw a conclusion that this necessity of having fresh water and being in control of the flood waters, by itself led to the construction of the first manmade dams.

Recent research has revealed small dams in southern Jordan that can be dated to the seventh millennium BC (9000 yrs ago!). There is still much we do not know about these dams, but even the fact that humans were capable of these levels of organisation at the very dawn of agriculture and organised society is astonishing. The dams of the Neolithic and early Bronze Age were designed just to withstand water pressure—not to prevent seepage. A layer of relatively impermeable soil used for sealing was observed for the first time at Hittite dams at Sarissa and Hattusa (47).

However the widely excepted earliest known manmade dam is The Jawa Dam in Jordan, 100 kilometres northeast of the capital city Amman. This gravity dam featured 5 (4.5 (47)) m high and 1 m wide stone wall, supported by 80 (50 (47)) m wide earth rampart. According to Vogel it was built out of two walls of basalt stones, with the fill between them made of clay, ash and soil. The structure is dated to 3000 BC (48). During his excavation Dr Svend Helmas discovered that the Jawa Dam was used in unison with a group of smaller dams located near the site for collecting rain water. This water was used in supporting the needs of a growing town of Jawa, which has been estimated to have quickly reached a size of 2,000 inhabitants before it collapsed.

The remains of another great dam from an early period are close to Cairo, Egypt. The dam is known as "Sadd el Kafara" near Wadi Garawi. A joint team of Egyptian and German scholars dated excavations to the old Kingdom of Egypt with C-14 analysis and archaeological findings which suggested its utilisation occurred at about 2650 BC. This is an earth filled dam 110 m long with base width of 98 m and top width of 56 m and height of 14 meters. The dam was built out of ashlars of limestone 30x45x80 cm with the smallest face pointing outside. The limestone was somewhat dissolved and eroded due to its long submergence unwater, so it could be presumed that this dam worked for a long time (47)[3].

Figure 43. Sadd el-Kafara dam, near Cairo Egypt built around 2700 - 2600 BC

The Roman dams

The oldest still standing dam dates from the 1st or 2nd century AD. It is a Roman dam at Cornalvo in Spain and it has been in use for almost two millennia. The dam was built with use of Roman concrete and it is 20 m high and 194 m long with a base of 26 m (49). Due to use of Roman concrete, they were able to build much larger structures than previous dams. Romans were great inventors and they pioneered construction principles for many different types of dam construction we know and use today. These include

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[3] Egypt may lay claim to many firsts and Broad found it strange that this first attempt in the world to build a dam of stone, most of which is still intact today, is not considered a mainstream site, likely to meet the curiosity of any serious archaeological visitor. "It needs to be made known and marked off for protection… With the increasing flow of modern traffic from the Nile Valley to the Red Sea, unless something is done, it is only a matter of time before it disappears altogether." **Cairo Museum, Egypt**

arch-gravity dams, arch dams, buttress dams and multiple arch buttress dams, as well as other engineering marvels of that time such as bridges, roads and aqueducts. The highest and the largest known dam in Roman Empire and in world until its accidental destruction in 1305 AD, was the Subiaco Dam near Rome, Nero's pleasure lake. Its record height of 50 m remained unsurpassed until its collapse. There is evidence of some 85 dams that were built by Romans, five of them still in use after twp millennia. Other ancient dams worth mentioning are the earliest known arch dam, Glanum Dam, France 1st century BC (12x3.9x18 m); the earliest known multiple-arch dam, Esparragalejo Dam, Spain 1st century AD (5.6x2.2x320 m) (50); the earliest description of arch action in such types of dam by Procopius (De Aedificiis II.3), Dara Dam, Turkey 560 AD; the largest in its time artificial lake (capacity of 90 million m^3), which is still in use, the gravity dam, Lake of Homs dam, Syria 3rd century AD (7x20x2000 m); the earliest dam-bridge (weir combined with arch bridge), gravity dam, Band-e Kaisar, Iran 3rd century AD (2x10–12x516 m); are just some of the great marvels of architecture left by Romans.

Figure 44. Roman, Cornalvo dam Extremadura, Spain

The dams in Asia

There are numerous springs and rivers that can trace their beginnings to the top of the world, the Himalayan glaciers. There are 19 big rivers of which seven are considered great "holy" Asian rivers - the Ganges, Indus, Brahmaputra, Salween, Mekong, Yangtze and Huang He, which provide a year-round water supply for more than two billion people (51). Some of the oldest and the most ingenious diversion dams and irrigation systems developed here from the start of Buddhism and the agriculture era onwards.

The oldest dam still in use in Asia is a diversion dam built on the Kaveri River; the Kallanai Dam built in the second century AD, located in the Indian state of Tamil Nadu. The dam was built to enhance the irrigation of the delta of Kaveri by Karikala Chola, considered one of the great rulers of that period. Kallanai Dam splits the river into four distributaries known as Kollidam Aru, Kaviri, Vennaru and Puthu Aru. The dam is 329 m long, 20 m wide and 5.4 m high, it is still in the excellent condition and use, although renewed and most likely altered in small amounts by the British colonialists in the 19th

century. The Kallanai Dam has survived to this day with all of its original purpose, the irrigation the 400 000 ha of agricultural land which has grown to million ha by different authors (52), (53).

For millennia, people from all parts of the Indian subcontinent have considered the rivers coming from Himalaya glaciers sacred. However today this rivers and their unique and in many cases endemic ecosystems are endangered by climate change and rapid glacier meltdown. The rate of movement of the Himalayan glaciers is palpable and varies considerably amongst them. In the Karakoram Range, the Baltoro Glacier moves about 2 metres per day, while others, such as the Khumbu, move only about 30 cm daily, which is still considered rapid (51). These glacial rivers nourish the lives of people in India, Pakistan, Bharat, China, Burma, Laos, Cambodia… providing them with essential drinking water, fisheries, as well as irrigation on which they have relied for centuries.

Sixteen such ancient irrigation dams are situated in central India, in a region of 750 km^2 around the Buddhist site of Sanchi, and these dams are also considered to be some of the oldest examples of ancient diversion dams that served for irrigation in Asia (54). Construction has been is thought to have started in the 3rd century BC and finished around the 12th century AD (54). It is hypothesized in the article "Ancient Irrigation and Buddhist History in Central India: Optically Stimulated Luminescence Dates and Pollen Sequences from the Sanchi Dams" that earliest phase of dam construction started with the rise of urbanisation and the establishment of Buddhism together with Buddhist monastic landlordism in central India between the 3rd and 2nd centuries BC. The main proposal is that these early dams were used in cultivating wet-rice. Similarities can be found with patterns in Sri Lanka, where monastic landlordism is attested from the 2nd century BC onward, and have also led to the working hypothesis that the Sanchi dams were central to the development of exchange systems between Buddhist monks and local agricultural communities (54).

Today there is a great environmental battle waged in the steep hills of the Himalayas. The governments of India, Pakistan, Nepal, Bhutan and China are planning to transform the Himalayan rivers into the powerhouse of South Asia by building hundreds of mega-dams to generate electricity (55). Numerous implications, both positive and negative have been discussed and widely elaborated upon in an excellent report from the non-profit organisation, International Rivers: "Mountains of concrete: Dam building in the Himalayas." The report elaborates on the possible impact of climate change that will jeopardize the viability of the hydropower projects as well as the safety of the dams, especially considering the recent devastation caused by the breach in the embankments of the Kosi River in Nepal (55). There are huge implications for these mega projects. The question of the quality of the investment has been raised as they will be planned for only 100 yrs with conservative figures of more like 50 yrs. They will undoubtedly influence the local climate, as with any water body being a thermal buffer, these reservoirs will be holding the heat of the summer months and creating hotter microclimates in the region. A more local shift to this example can now be observed in Austrian Alps in the farm of a local Agroforestry master Sepp Holzer, where his super small lakes still allow him to grow kiwi fruit. This will be explored in depth via his Hügelkultur approach in the agroforestry chapter.

But the point is what would these mega dams do to Himalayan glaciers?

Looking into this short overview of ancient dams from completely opposite parts of the world we can find correlations in dam development. This correlation may be the strongest with civic structure formations as with the military or monks but also in

establishment of land ownership and a clear aim to stay on the land, increasing its productivity and value. This then leads to the need or necessity to control the water and irrigation, which in turn gave rise to some of the first dams in the world, increasing the strong link between dams and agriculture.

Dams through the Middle Ages
Water control in Istanbul, formerly "Constantinople," can be traced to the ruling times of Hadrian and four of eight dams that were later built to provide water to the Golden Horn. The largest of these dams now forms the Buyuk Bent or Great Reservoir, with a length of 76 meters, height of 12,50 m and thickness of the base of its trapezoidal cross-section 10 m. (56)

The classification of Dams; different classification methods including ICOLD

Civil Engineering and its sub branches like Hydraulics and Water Resource Engineering and/or Management, Structural Engineering, Costal Engineering are usually the ones to deal with dam engineering. This branching of civil engineering science is widely diverse across the globe and education systems. This is why today we have so many diverse dam classifications as we have different engineering groups in charge for their design.

The most widely accepted classification system is provided by the International Coalition on Large Dams (ICOLD). As mentioned in the literature review, this system recognises two basic types of dams:

- large dams - which they track and
- small dams - which they do not monitor.

In this classification there are a few nuances and so the large dams are seen by ICOLD as "Large Dam- Grand barrage A dam with a height of 15 metres or greater from lowest foundation to crest or a dam between 5 metres and 15 metres impounding more than 3 million cubic metres, and defined in greater detail in the World Register of Dams" (57)

While there are over 100 000 smaller dams with storage over 100 000 m3 and millions under 100 000 m3, many are unaccounted for by international organisations.

The large dams are further classified by ICOLD as single or multipurpose dams. In both cases irrigation is the most common with 50 % and 24 % respectively, reaffirming the analogy with agriculture. (58)

Then there is classification of large dams by:

- Classification By Type of Structure

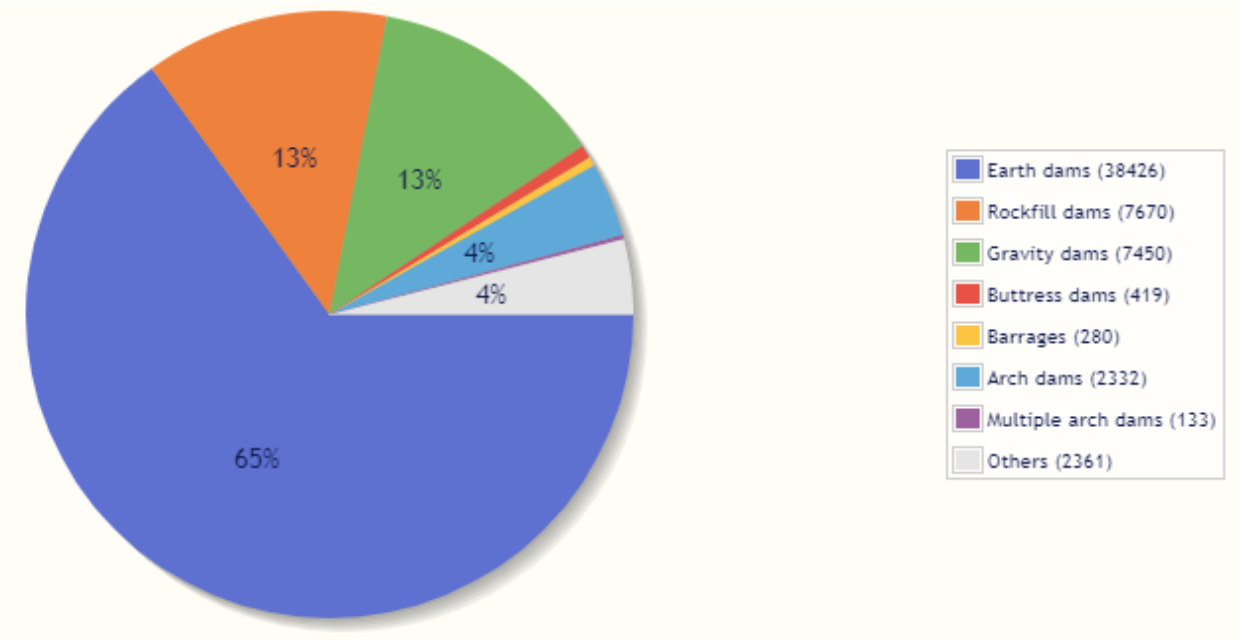

Figure 45. ICOLD Large Dam classification by dam type (58)

In this classification ICOLD sees 8 distinct of dam structure types. This classification can be broadened if looked from the perspective of materials used for the construction the material rigidity of dams:

- Fill-embankment-non rigid material dams

These dams are constructed with non-rigid material such as earth, tailings, rock-fill etc.

Earthen dams in this classification are divided into:

1. Earthen dams – gravel, sand, silt, clay etc.
2. Tailings dam – waste or refuse obtained from mines.

Earthen dams are provided with a stone masonry or concrete overflow (spillway) section. Such dams are called composite dams.

Rock-fill dams are spilt in two categories:

1. Rock-fill dams – rock material supporting a water tight material on the u/s (*upstream) face.
2. Rock-fill composite dam – Rock-fill on the d/s (*downstream) side and earth fill on the u/s side.

In some cases, part of the length of the dam is constructed as an earth dam and the rest (excluding the spillway) as a masonry dam. Such dams are called masonry cum earthen dams.

- Masonry-rigid materials dams

These are constructed with rigid material such as stone, masonry, concrete, steel or timber. Steel dams (steel plates supported on inclined struts) and timber dams (wooden planks supported on a wooden framework) are constructed only for low heights and occur rarely.

These dams are classified based on their function on:

- Storage dams- used to accumulate water and produce hydropower, irrigation or provide unobstructed water supply.
- Detention dams- mainly used to prevent catastrophic flooding, to hold the water and gradually release it protecting social structures.
- Diversion dams- used to divert waters from perennial rivers to irrigation channels.
- Coffer dams– are usually used to create a dry zone in water body during construction of a bridge for example. Coffers are used to create a type of a hole in the water body, from which the water is pumped out; in order to create optimal working/operating conditions for constructing a bridge pillar or similar water structure like highways.

Other large dam classifications that can be found within ICOLD are the following:

- Classification by Spillway Capacity
- Classification by Reservoir Capacity
- Oldest Dams
- Classification by Installed Capacity With Energy
- Classification by Irrigated Areas
- Classification by Volume For Flood Protection
- Classification by Resettled Persons

Dams are also defined by their use and in this case we have:

- Saddle dam

Figure 46. Ethiopia: GERD Generation Capacity Increases to 6,450 MW (59)

Figure 46. gives a great example of dam uses classification. In which saddle dams are mostly used so the water level can be higher within the reservoir or to limit the surface and extent of a reservoir for better efficiency or to protect fertile lands, etc. as shown on the picture. An auxiliary dam is constructed in a low spot or saddle through which the reservoir would otherwise escape. Dikes are commonly used for reclamation of

arable land from a shallow lake. This is similar to a levee, which is a wall or embankment built along a river or stream to protect adjacent land from flooding, but on a much larger scale.

- Weir dam

Figure 47. Bath's Avon Weir, England.

A weir (also sometimes called an overflow dam) is a type of small overflow dam that is often used within a river channel to create an impoundment lake for water abstraction purposes or for oxygenizing slower waters and which can also be used for flow measurement and retardation of flow.

- Check dam

A check dam is a small dam designed to reduce flow velocity, but it is also used to control soil erosion.

- Wing dam

Conversely, a wing dam is a structure that only partly restricts a waterway, creating a faster channel that resists the accumulation of sediment.

- Dry dam

Figure 48. Seven Sisters Falls Generating Station, Manitoba, North America.

A dry dam is constructed to endure massive water inflows in flood periods, it is made to protect and control flooding in populated areas. Otherwise they hold no water 80 % of the time and usually let the river to flow freely downstream.

- Diversionary dam

Figure 49. Patani Dam, Muang Yala district of Yala, Thailand

Very similar to a Wing dam a diversionary dam is a structure designed to divert all or a portion of the flow of a river from its natural course. The water may be redirected into a canal or tunnel for irrigation and/or hydroelectric power production. So the main difference is one starts from the lake the other from the river or stream.

- Underground dam

Figure 50. Underground dam

Underground dams are used to trap groundwater and store all or most of it below the surface for extended use in a localised area. In some cases they are also built to prevent saltwater from intruding into a freshwater aquifer. Underground dams are typically constructed in areas where water resources are minimal and need to be efficiently stored, such as in deserts and on islands like the Fukuzato Dam in Okinawa, Japan. They are most common in north eastern Africa and the arid areas of Brazil while also being used in the south western United States, Mexico, India, Germany, Italy, Greece, France and Japan.

There are two types of underground dams: a sub-surface and a sand-storage dam. A sub-surface dam is built across an aquifer or drainage route from an impervious layer (such as solid bedrock) up to just below the surface. They can be constructed of a variety of materials to include bricks, stones, concrete, steel or PVC. Once built, the water stored behind the dam raises the water table and is then extracted with wells. A sand-storage dam is a weir built in stages across a stream or wadi. It must be strong as floods will wash over its crest. Over time sand accumulates in layers behind the dam which helps store water and most importantly, prevents evaporation. The stored water can be extracted with a well, through the dam body or by means of a drain pipe.

- Tailings dam

A tailings dam is typically an earth-fill embankment dam used to store tailings — which are produced during mining operations after separating the valuable fraction from the uneconomic fraction of an ore. Conventional water retention dams can serve this purpose but due to cost, a tailings dam is more viable. Unlike water retention dams, a tailings dam is raised in succession throughout the life of the particular mine. Typically, a base or starter dam is constructed and as it fills with a mixture of tailings and water, it is raised. Material used to raise the dam can include the tailings (depending on their size) along with dirt.

There are three raised tailings dam designs, the upstream, downstream and centreline, named according to the movement of the crest during raising. The specific design used it dependent upon topography, geology, climate, the type of tailings and cost. An

upstream tailings dam consists of trapezoidal embankments being constructed on top but toe to crest of another, moving the crest further upstream. This creates a relatively flat downstream side and a jagged upstream side which is supported by tailings slurry in the impoundment. The downstream design refers to the successive raising of the embankment that positions the fill and crest further downstream. A centreline dam has sequential embankment dams constructed directly on top of another while fill is placed on the downstream side for support and slurry supports the upstream side.

Because tailings dams often store toxic chemicals from the mining process, they have an impervious liner to prevent seepage. Water/slurry levels in the tailings pond must be managed for stability and environmental purposes as well.

Dams could further be classified by the material used for their construction, to: Steel dams and timber dams along with other types. There are also unique types by design such as beaver dams and natural dams which help nurture biodiversity.

The importance of dam classification and dam conclusions related to dam structures
Important for this study could be a new type of dam classification based on the two basic types:

1) dam structures that slow down the water and hence create sediment depositions;
2) dams that do not obstruct the water and sedimentation patterns

Dams, sedimentation issues and their environmental impacts

Types of Reservoir Sedimentation:

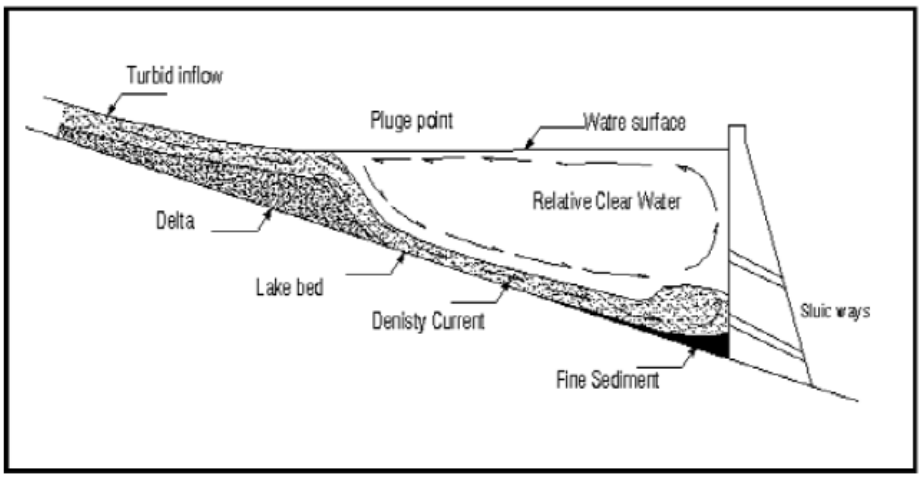

Figure 51. Types of reservoir sedimentation (27)

- Back water deposition
- Delta formation
- Bottom-set bed depositions
- Depress flow (27)

At the same time, the impact of sediment deposition in reservoirs and its consequential irrigation systems downstream can lead to serious reduction in reservoir storage capacities, which further lead to hydropower generation problems, banks flooding and ultimately negative impact on the socio-economic lives of the users, environment and the overall ecosystem. “Moreover, the sedimentation in the irrigation systems leads to water shortage and irritation management difficulties. On the other hand, sediment

deposition on the bed of the river course raises the bed level, hence leads to flood risks and loss of human lives and their properties.” (29)

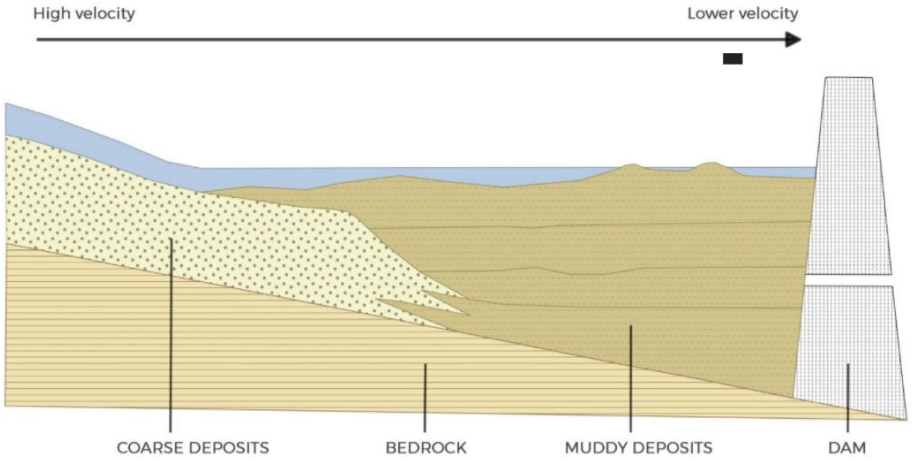

Figure 52. Visualisation of a dam siltation process by Eng. Tuija Pakkennen from Afforest4Future (60)


Figure 53. The appearance of a siltated dam - Malibu Dam, California USA by F4 Studios (61)

Once the dam has been built, the sediments are formed there are few ways to go about it now, as best described in a book by Dr Aras titled “Cost Analysis of Sediment Removal Techniques from Reservoirs”:

Sedimentation management:

“Nevertheless, in this study the basin water storage capacity management techniques used in World is categorized as follows:

1. Preventing Sediment Inflow into the Reservoir, Watershed Management

- Upstream Check Structures (Debris Dams)
- Reservoir Bypass

2. Sustainable Management of the Reservoir,

- Evacuation of Sediments from Reservoir

- Flushing
- Sluicing
- Density Current Venting
- Mechanical Removal
- Dredging
- Hydrosuction Removal System (HSRS)
- Trucking

- Management of Reservoir

- Operation Rules
- Tactical Dredging

3. Lost Storage Replacement Techniques or Decommissioning of Dam

(retirement of dam).

- Raising Dam Height
- Build New Dam
- Decommissioning" (62)

When the prevention of sediment inflow fails, as has been the outcome in the majority of cases, we look into sustainable management of the reservoir. What this entails is not actually connected to the sustainability itself but rather to keeping the available water volume intact. Many of these available options are considered highly destructive for the ecosystem and the riverine water life. Especially when focusing on dredging, the usual way it is now done, is to perform an EIA (Environmental Impact Assessment) study. This includes a survey and review of prior studies done by others to describe the physical, chemical, and biological conditions of the study area. An adequate evaluation of regional dredging and disposal needs will also be included in initial EIA; as well as a characterisation of physical and chemical properties of typical regional dredged materials. The properly developed EIA will also formulate alternatives for dredged material management and/or disposal, perform a preliminary evaluation of alternative management methods, and make recommendations for any further necessary evaluation.

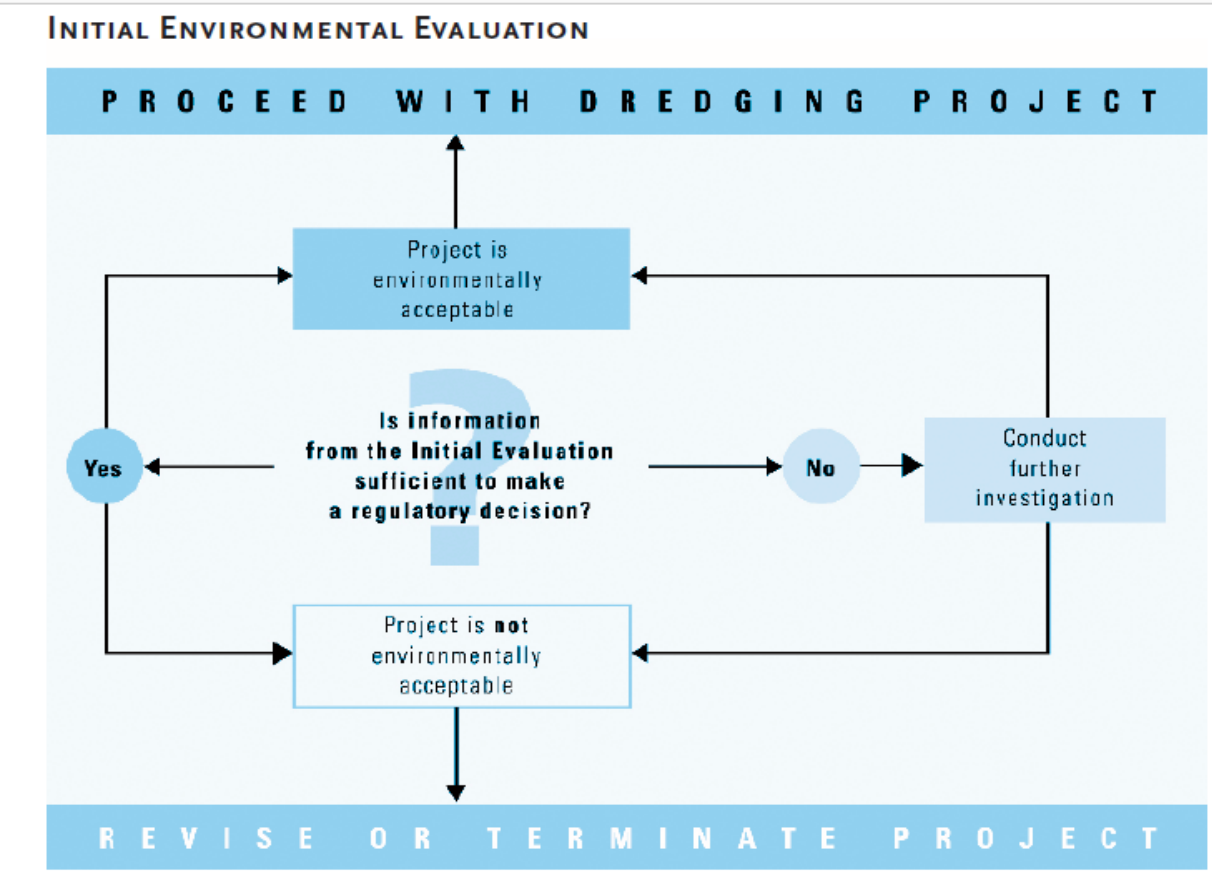

Figure 54. Predicted effects can be divided into short-term (less than one week) or long-term (more than one week) effects and near-field (less than one kilometre) or far-field (more than one kilometre) effects (63)

"Reservoirs have traditionally been planned, designed, and operated on the assumption that they have a finite (life), frequently as short as 100 years, which will eventually be terminated by sediment accumulation. However, the sustainability criterion was recently introduced by United Nation (UN) towards the end of the last century to suggest a minimum of 1000 years of operation for new designed reservoir projects. However, for existing reservoirs, sustainable sediment management should seek to balance sediment inflow and outflow across the impounded reach while maximizing long-term benefits. Traditional approaches to sediment management have not considered the sustainable use of reservoirs which resulted in losing reservoirs storage capacity rapidly, possibly as fast as 1 % per year, Mahmood (1987)." (29)

During the 20th century dams have become pervasive features of the world's river systems, with more than 75,000 dams above 1.5 m tall in the United States and 40,000 dams over 15 m tall elsewhere in the world we need elaborate decision-making methodologies such as the one developed by WCD or EIA. As for the accurate counts of small dams, the situation is best described as: "Smaller dams (i.e., below 5 ft~1.5m tall) in the United States likely number in the thousands (American Rivers and NPS 1996). Nearly 80 % of the total discharge of large rivers in the northern third of the world is impacted by river regulation (Dynesius and Nilsson 1994)." (26) Not even in the developed world do we have an exact account for all the dams. This has often been one of the arguments used by many environmental advocates when promoting dam removal as we cannot perform a WCD or EIA assessment of a dam when we do not know of its existence or exact location. Hence how could we know of its direct or indirect impact to the river ecosystem or that specific migratory fish that populates our presumed river? To the best of this author's knowledge there is no such data set. There are some new

research groups forming in the United States focused on using remote sensing and machine learning in training algorithms to recognise the looks of small dams and in this way try to account for millions of small dams worldwide of which we are not now aware. However, we are not yet close to this. It will be perhaps another 2-3 years before we can compile these numbers accurately.

Dam decommissioning can usually be classified into 3 types:

1) full decommission leading to full dam removal,
2) partial decommission – meaning partly removing the dam, usually part of its height, shortening the dam,
3) and last Changes to Dam Operations (Modification), not leading to removing the dam but rather repurposing the dam, reservoir and/or its surroundings, which is what usually happens so far.

However, in recent years dam removal has become a movement across the Americas, partly due to great environmental concerns regarding migratory salmon fish, but also fuelled by advocacy from the Freeing the Rivers movement, Patagonia Dam Nation and similar environmental organisation. However even when "freed" the question of pros and cons, of actual benefits of removing the dam vs maintaining/ modifying it remains a question?

As concluded by M. Doyle in "Stream ecosystem response to small dam removal: Lessons from the Heartland": "… ecosystems may fully recover to pre-dam conditions, although this may be unlikely in many cases. Even if full recovery occurs, the timescales over which different attributes recover will vary greatly and may be perceived by the public or management agencies as not recovering at all." (64)

A very different yet valid point was raised and discussed in depth throughout the book written by A. T. Bednarek, "Undamming Rivers: A Review of the Ecological Impacts of Dam Removal" where she describes dam removal as "…an alternative technique for returning active sediment transport to a river. When a dam is removed, fine sediment is mobilized from the slow-moving reservoir and redistributed, exposing gravel, cobble, and boulders within formerly impounded areas." (26)

In the book she processes the subject of dam removal trough different objectives and many different impact lenses, always keeping on "the green environmentalist" glasses. Some of the important points she goes through in her book is sediment release; as it may have served as a bio filter since the construction of the dam, sometimes absorbing the heavy metals and other pollutants up to a level of becoming toxic and hence a direct thread if suspended into the local ecosystems.

"Sediment Release"

The full or partial removal of a dam results in sediment movement downstream. In most cases, the impoundment above the dam will have been accumulating sediment for many years and, in some, the impoundment may be almost completely filled (Kondolf 1997).

Contaminated sediment is important consideration for dam removal (Murakami and Takeishi 1977, Stone and Droppo 1994, Chatterjee 1997). Because small-size sediments tend to sorb (attach) relatively more contaminants than coarse sediments due to their large ratio of surface area to volume, a release of fine sediment impounded behind a dam may constitute a major hazard to the river (Stone and Droppo 1994, Wood and Armitage 1997). Thus, toxins released upstream are both more likely to settle out of the water column within a slow-moving reservoir and to accumulate in the fine sediments

located therein. Contaminated sediments can also become enmeshed in algal mats, or in some cases, attach to algal cells and eventually accumulate in higher trophic levels." (26)

She finds the short-term ecological impacts, such as sediment release, as important to the ecosystem as the long-term benefits.

"Short-Term Ecological Impacts of Dam Removal"

The process of dam removal itself has various short-term impacts on the riverine ecosystem. Some of the most significant impacts include sediment mobilization, contaminated material, and an increase in the threat of supersaturation. The other important short-term ecological impact with dam removal can be supersaturation, also nicely elaborated in the book: "Supersaturation."

Supersaturation could also be a concern with some dam removals. A rapid drawdown of a reservoir during removal will produce short-term increases in velocity and pressure, which increase chances for gas-bubble disease in fish (Weitkamp and Katz 1980, Wik 1995).

During a 1992 drawdown test on the Little Goose Dam (on the Snake River in the Pacific Northwest), dissolved gas supersaturation increased, along with turbidity and loss of reservoir fish and insects (Wik 1995). However, these losses and changes were short term and did not affect overall populations (Wik 1995). If the removal is gradual, sharp increases in velocity may be avoided, lessening the chances of supersaturation." (26) Unfortunately, there are only a small number of peer-reviewed studies available on completed dam removals and their impact on the environment and biota. "Although there have been a few reviews concerning the environmental and socioeconomic effects of dam removals (see Shuman 1995), so far none have fully addressed the impacts on crucial ecosystem components. These can include the flow regime, habitat, sediment transport, and connectivity of a river some of the most important factors for healthy river ecosystems (see Poff and others 1997)." (26)

The third category of Dam Modification, the very opposite to dam removal, can leave us with a very different set of problems, especially in relation to sedimentation. "The average rate of relative sea-level rise in Louisiana is around 10 mmyr–1 – approximately 5 to 10 times the global mean value. This high rate is largely due to natural land subsidence, caused by sediment loading and compaction in the vicinity of the Mississippi River delta. Submergence due to the high rates of relative sea-level rise may contribute, in part, to the severe erosion of barrier islands and coastal wetland losses of near 100 km2 yr–1. However, damming of upstream tributaries and other flood control measures have cut the sediment load of the Mississippi River by 46 % since the 1900s (Wells 1996). The reduced sediment supply to the delta is insufficient to compensate for the high subsidence rates, and thus the shoreline is rapidly retreating." (17)

This brings us back to coastal aquifers and their fragility in face of climate change and sea level rise, and now we see the relation between the coastal aquifers and how they can be jeopardized by dam construction, withholding the sediments and allowing for slat water intrusion faster than predicted. "Reduced sediment loads to rivers through damming increases coastal erosion and deterioration of coastal marine ecosystems. Following completion of the Aswan Dam in 1964, the sardine fish catch in waters adjacent to the Nile River delta was reduced by 95 % in response to reduced nutrient discharge and the delta shrank rapidly (Hu et al 1998). Recently, with the increased use of artificial fertilisers and the expanded croplands in its delta region, nutrient loads to the Nile have increased and some fisheries stocks have improved or been replenished

(Nixon 2003)." (17) Here it good to note that the author would add this to WCD necessary assessment as a mandatory field to be considered. The correlation between dam construction on high sedimentary rivers that are in close connection to the costal aquifers, the lack of sediment deposition and salt water intrusion into the coastal aquifers, needs to be looked as both short term and long-term ecological impacts on the environment. Short term impacts being the current intensification of water stress, which is then not only environmental but also a socio-economic factor. Shore erosion and change of the costal border line ecosystems as environmental and the long one, prolonged water stress and our uncertainty on how much of the aquifer will be affected with brackish waters for how many generations.

Although sediment fluctuations have been noted throughout our history, "Historical land-use and sediment discharge response has come full circle for the eastern seaboard of the USA" (Pasternack et al 2001). After European settlement (post-1740) sedimentation rates increased eight-fold through early deforestation and agriculture (1750–1820), then increased another three-fold during the period of peak deforestation and intensive agriculture (1820–1920), and finally were reduced by an order of magnitude (i.e., close to pre-colonisation values) during the period of dam building and urbanisation (1920 to present). A similar set of histories for other regions must be completed before we can understand and predict the global flux of sediment." (17) This could give us better insights not only into costal sediment fluxes, but also costal aquifers and their fluctuations as well as the better ability to use advance tools, like remote sensing, LIDAR, satellite images, cloud computing, artificial intelligence to create more accurate predicting models, and elevate future water stress with proper dam management.

All such tools would make for better informed dam decommissioning decisions, especially ones not forced out by different groups, but rather pure science. Remote Sensing can be used to track the sedimentation levels of a lake more accurately: "It based on the repetition of similar satellite images at regular intervals of 2 to 5 years on areas of dams. The remote sensing technique helps to calculate the present storage capacity, which is compared with the original capacity and reduction in capacity over a period of time is attributed to silt deposition. Remote sensing techniques for estimating sedimentation are useful only for lakes and reservoirs where rise and fall in water level is a regular phenomenon." (26) Cognified with artificial intelligence, this could give accurate predictions of the available water volume for the next 10 to even 100 yrs, once the AI neural pathways have been trained enough.

Any of the combinations of new high-tech advanced technologies can increase the quality of life for the people living in the dam surroundings, as well as provide more security for water stressed areas. These arid regions have many different purpose dams and many small and medium dams which are neither monitored nor regulated well enough. Using remote sensing could give abundant informed and intelligent decision-making power to the local governments. Small dams, in arid zones, flash flood regions, or deforested areas, are considered very fragile.

"However, the lakes of these dams, which are sediment traps across their catchments, are extremely threatened by siltation which reduces their lifespan while hydrologists recommend that only dams whose life exceeds 30 years may be used for drinking water or irrigation valuations [4]. In fact, dams" siltation is a natural and very old phenomenon. Examples are Marib Dam in Yemen constructed 1100 years AC and Kebbar in Iran in 1300 AD [5]. In addition to reduction of lifespan, siltation causes the elevation of the flood's magnitude and makes the downstream more dangerous. The safety of embankment is also threatened because of the increase of the pressure's silts on the

wall. Therefore, the control of siltation is an inevitable step closer either to having global values of erosion rate or sediment yield in watershed [6] [7]. This control is also important for the management and the optimization of these structures. It allows updating the filling curve of dam (Height-Volume Curve) which may be superseded by subsequent deposition [8]-[13]. Erosion, sediment yield and siltation have been studied by much researcher [8] [14]-[19]. The majority have been focused on the characterization and regionalization of siltation, and they have tried to produce practical models and monograph for each area [9] [12] [20]-[24]. Some researchers are oriented towards identification and assessment of erosion rate's based on geometric, hydrological, lithological, geomorphological and climatic characteristics of the watershed [25]-[30]." (65)

We have been trying to manage sedimentation for centuries now, and are finally in agreement about the importance of measuring and monitoring not only the reservoir itself, or the river, but its whole basin including the surrounding landscapes whose erosion leads to faster loss of storage, especially in small reservoirs. "Small dams and hillside lakes which are usually located in fragile environments with low economic activity play a vital role in the sustainable development of these areas. Arid and semi-arid areas are most affected by recurrent drought periods, hence followed by the construction of these dams for water conservation. However, these small hydraulic structures are greatly threatened by siltation, which limits their durability and makes their aim uncertain.

"In fact, the scourge of the dams silting is not new. It tormented the managers of these structures due to antiquity and will continue to do it. This is a natural phenomenon; therefore, the prevention remains the most efficient way to mitigate it. The measurement of siltation in dams is an important step to understand and master its operation. This direct measurement of siltation is not always easy and attainable to the responsible of small dams and hillside lakes. In this context, we would like to propose a new method of measuring siltation, less expensive than those currently used. This new method is validated by the more precise method as bathymetry survey and others recognised methods in five hillside dams. Thus, this method could be recommended for the measurement of siltation in the small dams and hillside lakes especially by the NGOs and communities who have limited technical and financial resources. The adoption of this method will allow studying a larger number of small dams and hillside lakes sites. The measures will help understand the specificity of each sub-basin, then to identify the significant indicators of siltation. Finally, we can use these detected indicators for studying the proposal best sites for the future small dams." (26)

Currently we have a few different methods of on-site sediment measuring and they are described as: "There are several modelling tools available to estimate rate's erosion and sediment transport assessment. One of them, RUSLE (Revised Universal Soil Loss Equation) is commonly used as a base to produce specific models, depending on the area. Models such as watem/sedem [31], EPM model [32], SATEEC [33] and AGQ or PISA [34], require significant data for each watershed which is difficult for small watersheds because of the absence of the monitoring station. So, the direct measurement methods such as bathymetry are more reliable. After bathymetric survey, the silted volume is calculated by different methods: Kolmogorov [14], the method of average height and general method [8] [15]. Aerial stereography is another method based on overlaying aerial photos of the lake taken at intervals of time from two to five years [9]." (65)

However, the advantage of novel remote sensing methods for sediment measuring and monitoring can prove to be much more cost effecting in terms of small and medium dams, like the following method discussed in the article "Practical Method Proposed to

Estimate Silting's Rate in Small and Hillside Dams": "The advantage of the new method is that its cost ten to twenty times less than the bathymetry survey. Therefore, it is recommended for users of small dams and hillside dams who generally have limited financial and technical resources. The new technique has a scientific contribution since it allows the estimation of sediment transport in the sub watersheds and used in the screening of future sites of small dams and hillside lakes." (65)

First article describing the core process which received a patent for methodology for afforestation

Abstract

In a world which will be home to 9 billion people by the middle of this century, producing enough food and other vital resources is likely to be a substantial challenge for humanity. Today there are tens of millions of hungry living in Africa. These people are missing not just food and potable water but also tap water, sewage, electricity, jobs and other living amenities. Egypt is one of the most populous countries in Africa and the Middle East. The current population is over 81 million people (66) who live mostly on the banks of the River Nile. International organisations estimate that in 2050, Egypt's population will be 113 million (67). However, estimates of local media approach 200 million (68). As most of the country's landmass is desert (with less than 4 % (69) being agricultural land), and due to the fact that this is coupled with increasing mass migration towards the cities and loss of arable land each day to urbanisation, there is an urgent need for a new approach to deal with the overpopulated Nile Valley.

The alluvium that used to be Egypt's natural fertiliser is being sedimented behind the Aswan High Dam, producing "the sediment phenomenon" and Egypt one of the largest users of fertilisers among developing countries. With high levels poverty, especially in terms of food and arable land, it would be greatly beneficial if this "sediment phenomenon" could be used as Egypt is in dire need of new arable land. The consequences of building the Aswan High Dam have been charted by many articles and scientific papers since the erection of the dam, yet there has been little change in overall usage and development towards a solution. There have been many changes in terms of the environmental, habitat, social and cultural development of Egypt and Sudan affected by the dam, but there are still many questions concerning the dam and its surroundings which stay unresolved. This research aims to develop a sustainable solution for future needs in terms of food, healthy soil, energy, habitats and new job opportunities and contribute to resilient solutions.

Keywords: Sahara, green Sahara, de-silting, mud pipeline, sustainable transport, logistics, resilience, Aswan High Dam reservoir, geoengineering, afforestation, sustainable development

Introduction

Egypt is located on the North of the African continent and has been perceived as an African, Middle Eastern and Mediterranean country. It has an area of 1 001 450 km2, of which only a sliver around the River Nile is arable, about 35 380 km2, less than 4 % of its total surface (69). It is the 15th most populous country in the world and the 3rd most populated in Africa, with only Nigeria and Ethiopia ahead of it, respectfully (70). Its capital, Cairo is the 11th most populated city in the world (71). Cairo is situated at the downstream emergence of the Nile delta. The country's main lifeline, the Nile River, has formed a fan-shaped delta plain of some 22 000 km2, with two major distributaries,

the Rosetta and the Damietta, which link the upper delta apex (the mouth of the Cairo valley) to the sea (72).

Figure 55. Research location – Google maps

The Nile River is considered to be the longest river in the world, running 6 670 km from its remotest southern source, the Ruvyironza River, to the Mediterranean Sea (73).

With Cairo growing by the day at the expense of the arable land surrounding it (74), acquisition of arable land from the city borders and outskirts is becoming Egypt's greatest problem. An increasing number of people are moving towards the cities and as a majority of Egyptian cities are located in the Nile Valley, one can easily see the problem arising: Egypt is losing its only arable land at an increased rate and is thus *in growing need of new agricultural land.*

The Nile River alluvium has been the life source for the people living along its shores, especially for the farmers and traditional brick makers of Cairo, making the land very fertile. Building of the Aswan High Dam began in 1960 and in 1972 the Aswan High Dam Reservoir was formed, known in Egypt as Lake Nasser and Lake Nubia in Sudan. In this article we will refer to it as Lake Nasser. This lake has a total surface area of 5 250 km^2 and 9 802 km of shore line at the maximum water level of 180 m Above Mean Sea Level (75). Lake Nasser extends for 500 km, 350 km in Egypt and 150 km in Sudan (76), with an average width of about 13 km and maximum width of about 60 km at the maximum water level of 180 m. The maximum depth of the lake is 110 m at the maximum water level of 180 m, with an average depth of 25 m in the Egyptian part.

All dams are categorised and listed by the International Commission on Large Dams (ICOLD). Using the ICOLD classification system, the Aswan High Dam Reservoir is classified by reservoir capacity as the third-largest in the world, with only Kariba, Zimbabwe and Bratsk, Russia being larger respectively (77). Before the construction of the lake, the annual income of sediment varied from 50 to 250x106 metric tons or on average 135x106 metric tons of fertile alluvium silt (78) which was transported to the shores of the Mediterranean. With the Nile being one of the world's great alluvium-rich rivers it is no wonder that such great amounts of alluvium were transported, most of which is now trapped behind the dam. The lake itself is currently not in danger of overload by alluvium; it has a volume of 162 km3 (78) that is divided into three volumetric zones:

1. Dead storage zone 31 km3 below 147 (AMSL) (78)
2. Live storage zone 90 km3 between 147-175 (AMSL) (78)
3. Flood control buffer zone 41 km3 from 175-182 (AMSL) (78)

The Sudanese part of the lake has so far lost 80 % of its live storage capacity. This may well be the reason why the project "The De-silting of the Lake Nasser" has been added to the list of projects to be financed by the World Bank (79).

It is estimated that today, on average, the total annual suspended sediment weight entering Lake Nasser is 133.54x106 metric tons (78). About 97 % of this amount precipitates while the remainder (3 %), which is estimated to be $4.0x10^6$ tons a year (78), passes through the Aswan High Dam, because of the density currents, into the downstream stretches of the Nile River (75). Effectively, Lake Nasser traps annually 129.54x106 metric tons (78) of the total suspended sediment entering the reservoir. Each year, 4 million tons (80) of silt continues its way through the dam and into the Mediterranean, but due to the loss of velocity of the river, which has been degrading from 0.52 m/sec in 2000 to 0.46 m/sec in 2001, not all 4 million tons reach the shores of the Mediterranean (80). The calculated amount of deposited sediments on the bottom of Lake Nasser varies from 2.5 10^9 m^3 although this figure is from 1995 (81) to 5 billion tons or 4.95 x109 m^3 in 2004 (78), or 6,284 10^9 m^3 (80) with it being estimated that up to 7x109 tons will have accumulated by the end of this decade. According to El Gammal, the total storage capacity of Lake Nasser in 1964 was 9 115 Mm^3, by 1977 this had been reduced to 7 904 Mm^3, by 1988 it was 7 293 Mm^3, in 2000 it was 4 930 Mm^3, and by 2006 capacity was 4 148 Mm^3, meaning it has lost more than half of its original storage capacity (80)

Dredging as a means of freeing the blocked passageways has a long history, especially in countries such as the Netherlands, where it has been used successfully for hundreds of years. The same basic principle of dredging will be proposed in this article, adjusted to make the afforestation of the Sahara easy and simple. The remodelled and redesigned system of dredging will fit our purpose, with some added systematic changes, and make great use of the excavated material, which will be deployed in the afforestation of the Sahara Desert.

Problem statement

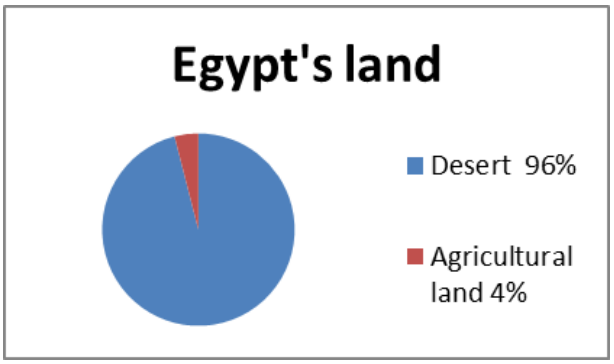

Figure 56. Egypt's land use

Out of Egypt's approximate 40 000 km2 of agricultural land 30 180 km2 is arable land, making up just 3 % of the country's total surface (82) and with most of this land being in the Nile Valley. The Nile Valley is also the most densely populated area of the country, with most of Egypt's cities being located within it. Migration towards the cities is accelerating among the country's rural population, making the level of urbanisation in the Nile Valley and the subsequent loss of arable land very high. Considering that Egypt's growing population is estimated to reach 113-128 million or perhaps even 200 million by 2050 (67) and that it is already the third most populous country in Africa, all Egypt's needs in terms of food, water, new habitats, new arable land and energy are and will continue to be constantly rising. And let us not forget that today Egypt is the biggest importer of wheat with 10,700 (1000MT) per year (83).

Since the construction of the Aswan High Dam the fields in the Nile Valley that used to be flooded annually are no longer flooded and are now irrigated. This land is now being

irrigated through a system of canals around the shores of the Nile, but without annual siltation and the annual inflow of rich nutrients. There are now high rates of salinisation because of the geographic position and they are faced with high soil degradation and leakage of overused fertilisers into the river, making the environmental situation worse. Egypt is one of the largest users of fertilisers in the developing world with an overall usage of 575.4 kg/ha (84), putting it 61st in the world on the list of fertiliser consumption per unit of arable land (85), even though it has all the preconditions not to be.

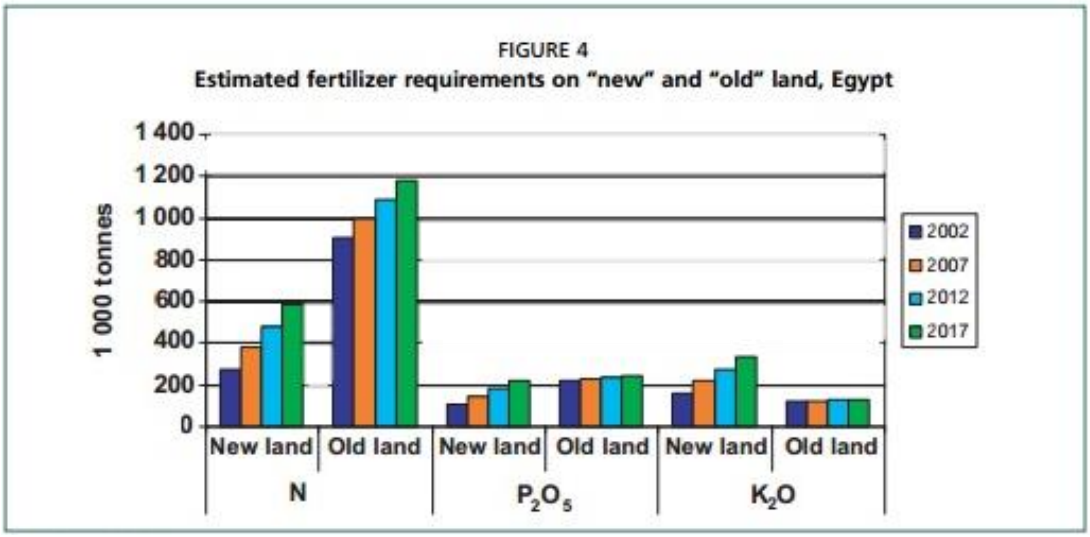

Figure 57. Estimated fertiliser requirements in Egypt (86)

This paper proposes a project for the de-silting of Lake Nasser and the use of these sediments in making new arable land in the Western Desert of Egypt.

The Aswan High Dam is the dam which causes Lake Nasser to form. It is an embankment dam, and falls into the rock-filled subcategory, as it is made of granite rock and sand and provided with a vertical cut-off wall consisting of impermeable clay. The reservoir makes an irrigation system for downstream arable lands. However, the dam does not solve the problem concerning the accumulation of the alluvium brought sediment: silt.

This study intends to see the best solution for the usage of sediments settled at the bottom of these lakes, in particular at the bottom of Lake Nasser. Over 40,000 large dams categorised by ICOLD as having been built in the 20th century (87), mostly on mountain rivers, are the rivers which carry the greatest amount of sediments, like the Nile.

Since this reservoir is one of the largest in the world, by solving Aswan's problem we would also be solving a lot more. Finding a solution to the Aswan alluvium problem through its meaningful, sustainable transport and possible usage we will be able to implement the acquired knowledge and new discoveries in new endangered lakes with smaller volumes. These include Serbia's Djerdap Lake which is formed by the River Danube (whose dam has already experienced turbine failure due to silt), Albufera Lake in Spain (where they have already carried out some research on the use of bottom lake sediments (88)), Roznów Lake in Poland, the Yangtzekiang, and the Three Gorges Dam, all of which will have to overcome this issue in the upcoming years.

On the local level a major issue is that Egypt needs new arable land away from the urbanised Nile Valley and that in the near future it will have to address the problem of rising silt in its lake. The Egyptian government has been trying to respond to this first

challenge through its numerous attempts to populate the Western Desert for half a century now.

At the same time, on the global level, we have the issue of global climate change, and our research is aimed at both addressing this and Egypt's need for new arable land outside of the Nile Valley. Our project relies on a geoengineering technique, afforestation, to try to make a positive change in the local climate that would affect global climate in a positive manner and help prevent *Global Warming*. We seek to make a totally self-sustained agro-forest ecosystem by using afforestation through intercropping and Permaculture as a base for our research, which would provide land, food, work and shelter for its inhabitants.

Research aim

The aim of this research is to explore the possibility of extracting and sustainably transporting the sedimented alluvium trapped at the bottom of Lake Nasser and to examine its application in land reclamation by using these rich sediments to make new arable land from sand in Egypt's Western Desert. The research aims to define all possible routes as well as all available means of sediment/alluvium transportation through the desert.

There is one final goal: to make new arable lands/fields that connect the existing oases in the Sahara Desert which provide new working opportunities, new habitats, new roads and green electricity, whilst also causing a shift in migration paths out of the Nile Valley and into the new valley.

This will facilitate saving some of the existing agricultural land around the Nile Valley from urbanisation and preserve the oasis climate within it. At the same time, land reclamation with specifically proposed crops and crop rotation schemes will play a major role in triggering a shift in the relationship between the Sahel and the Sahara (which have occurred numerous times throughout history. It will then be possible to have an independent agro-forest ecosystem in 100 years" time, going beyond irrigation projects and making this project a "beyond" sustainability approach to life on earth.

Project steps

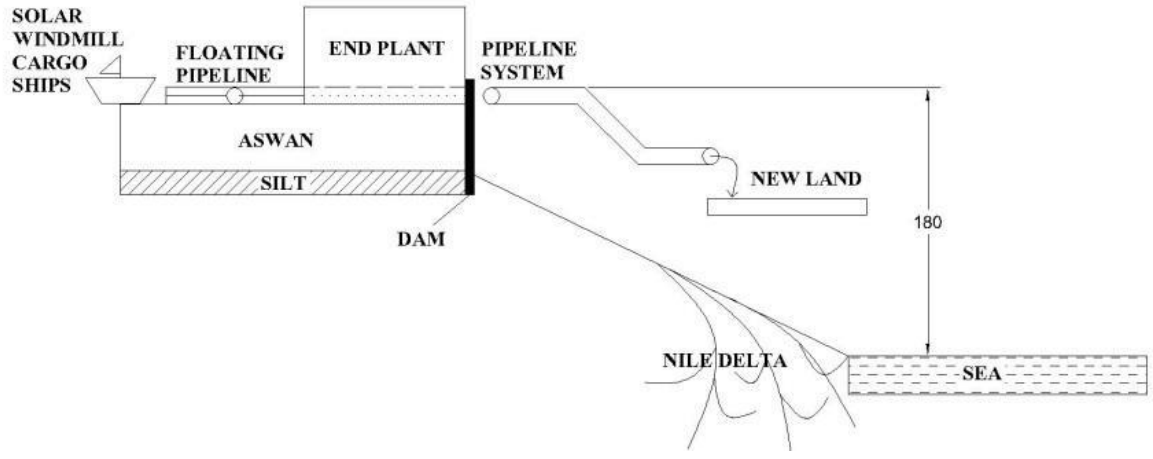

Figure 58. Schematic view of the system, author

An overview of the proposed system is as followed: the system will start with a dredger collecting sediments from the bottom of the lake, which will then be deposited in the

ship's tank and transported to the main cargo ship or pumped through a floating pipeline. In both cases it will arrive at the main processing plant and from there it will be grinded and mixed, rid of excess water and pumped into the purpose-built pipeline that will make its way through desert.

From there onwards mud will be deposited on sand primarily to make new arable land, will be used as fertiliser, or will be transported along the delta shores to increase the land fertility. The main purpose of this pipeline will be to make new green areas that will connect the existing oases, starting from the Kurkur Oasis and leading to the oases of Al Kharijah, Ad Dakhilah, Al Farafirah, Al Bahariyah and continuing all the way to Siwa Oasis, connecting all the existing green areas to form a new green strip, path, valley and make one new unified green region with its own micro climate. Through this approach and by providing the land with nourishment for the initial period of 100 years, we will give the Sahel an opportunity to spread deep into the Sahara, making it green once again. By helping nature "flip the switch" through giving it a little push in the right direction, we can have a great influence on global climate not just by relying on afforestation as our main method but by influencing micro climate at the right location and for the right amount of time to trigger already accruing historical climate changes.

First step: Choose the location for the pilot project

Location	I Northern site (near the AHD towards Kurkur)	II Eastern site (at Kushtamnah peninsula)	III Southern site (near Mubarak pumping station)
Urgency for new arable lands	6	2	4
People (existing settlements)	6	2	4
Abundance of silt (bottom lake sediments)	2	4	6
Representativeness	4	2	6
Political will	4	2	6
Accessibility by water	2	1	3
Accessibility by land	3	1	2
Infrastructure in water	2	1	3
Infrastructure on land	3	1	2
Existing agricultural land	1.5	0.5	1
Operation and Maintenance	1.5	0.5	1
Expected costs	1.5	0.5	1
Available funds World Bank	1	0.5	1.5

Sum	37.5	18	40.5

Figure 59. Table of the location determination

We will consider three possible locations for the initial plant, as they are all convenient for the later exploitation, starting from north to south:

1) The first possible location would be near the actual Aswan High Dam, on the western shores of the Nile, and would be suitable as a pilot plant as the infrastructure is already there. By choosing this location we would be deciding to follow the river's course downstream and enrich the green areas along the shores of the Nile. This course would lead us in the direction of trying to expand the existing green areas into the desert, helping to acquire new land and in this way compensating for the land that has been lost due to city sprawl. However, this location would not lead people out of the over-populated Nile Valley and would not be the best example of land reclamation from the desert, as the micro climate in the desert is more suitable for plant growth. It would, though, be a very good location for the pilot project as success is nearly guaranteed, considering the already existing population to serve the pilot and benefit from it. In this case the pilot would run for 100 km following the Nile's course. A further extension of the course after finishing the pilot could be directed towards Cairo. After reaching Cairo, the pipeline could then expand towards the Faiyum Oasis, connecting it to Siwa Oasis. When observing this particular location, we have to factor in the ships which would have to travel longer, as the main deposits of quality silt are further upstream at Abu Simbel. There will be no need for tunnels or additional pumping stations at the main station which could be located within the dam environs.

2) Kushtamnah is a location which should be considered as a very last, third phase of the project, after all other locations have become green and if the project is being developed towards the Eastern Valley. The location of the plant should be positioned on the Kushtamnah peninsula which enters the lake on the east side, so as to make it easily accessible for the ships, and which means less investment in floating pipelines. This location is mostly unsuitable as there are no big population hubs in this area and the infrastructure would have to be developed entirely from the ground up.

3) The third location is in the vicinity of the Mubarak pumping station, where the development of the Western Valley already started in the 2000s. In this area there are several irrigation projects which are to some extent successful but are all highly dependent on human presence. Connecting the Toshka lakes with Baris could be a suitable pilot project as a built-up infrastructure already exists in this area and the distance between the locations is around 120 km. After the pilot, the project could continue on from Baris to the Kurkur Oasis, with an optional second plant being opened in the vicinity of the Kurkur Oasis. Combining the power of both pipelines joined at Baris we could then construct a pipeline to Al Kharijah and onward to Ad Dakhilah, Al Farafirah, Al Bahariyah all the way to the Siwa Oasis and the Faiyum Oasis, making the oases even greener and more fertile while at the same time connecting them along the way with a green strip of arable land. Using a double pipeline would provide us with the option to stop using the silted irrigation after 5 years and switch to plain water, optionally from Kurkur. This would enable the prolonged usage of existing silt in overcoming desert, and also give an option to go back to a silt pipeline if the need for fertilisation occurs. With some technical adjustments we could use a single pipeline in a more or less similar fashion. This would make a new valley, a Western Valley region that would complete the circle of greens and that will have its own micro climate and will be self-sustained after an initial 100 years of monitoring.

Out of the three locations, the most northern and most southern are the most suitable for pilots. Both already have an infrastructure built up around them, and both have a work force, (although the majority of the population is concentrated along the shores of the Nile). This gives the advantage to the northern location as it could serve the greater number of people. However, the southern location has been part of a government plan and project for resettling the population away from the Nile for years now. Since General Nasser the Egyptian government has been trying to enable living conditions in the Western Valley (this is their name for this region of possible green lands along the oases). This southern location would also give the most accurate results in terms of a pilot project, as it is in a desert away from the influences of the River Nile and its Valley's climate, humidity and other influences. These clarify why we chose the southernmost location for the pilot project and is herein referred to as the end plant location.

In further research we took the following into consideration: the chemical composition of sediments that was monitored by the Aswan High Dam Authority and the Nile Research Institute data from 1973 to 2003, first in 7 different locations, and now in 15 locations, and which continues (78). This will help us decide on the best location for the pilot, the new fields and the new habitats. In an experiment done with the dredged materials from the Roznów Reservoir it was proven that they can improve the properties of the sandy soils of the area. It was demonstrated through various similar projects that the application of bottom sediment as an addition to the light, very acidic soil causes an increase in the crop yield due to the improvement of the physicochemical properties of the substratum and a possible limitation of the uptake of potentially toxic trace elements which the experiment successfully dealt with (89). Another relevant example is the Abulfera Lake. Both researches give us inputs on our desired effects from the use of bottom sediments. The Abulfera Lake sediments have a fertiliser effect on sand, which is our most wanted outcome. We can conclude that by using the bottom lake sediments, the effect on plant growth is substantial and could affect the land salinity with efficient planning in a similar way as they increase the sandy land quality.

Second step: Sedimented alluvium composition and characteristics

The Nile carries a great mixture of soils rich in minerals, which originate in the Blue and White Nile and gather anything that is in their way from the Tana and Victoria lakes, with all of this being sedimented upon arrival at Lake Nasser. This is why we can identify some very ancient sediments and black sands in the excavated mud. In a study on de-silting Lake Nasser (78) by B. Abulnaga and S. El-Sammany, sediments rich in minerals were identified which consisted of silts and different grades of sand and included black sands from 3 % of the silt to 15 % of the sand by weight concentration. These sands" minerals were exposed to magnetic separation methods to extract titaniferous minerals. Some were found to exhibit strong magnetic properties and were separated from other weaker minerals. Samples were also exposed to X-ray refraction and spectrometry to identify three principal minerals in the sediments: thorianite, uraninite and ilmenite. The study indicated that these minerals had traces of radioactive elements that tended to affect the formation of organic matter in alluvium once used for agricultural purposes in a positive way, as shown in Lake Roznów case study (89).

In the study a little radioactivity has been shown to increase the yield of Italian ryegrass and maize and the use of the bottom lake sediments is considered to be more than helpful for organic growth, as they used it in Ancient Egypt. By applying the same logic, we will therefore not need any artificial fertilisers, even in three crops per year schemes, if we plan the crop rotation in an integrated way with careful intercropping,

plan the smart use of invasive weeds and clover as fertilisers (90) and mass builders at the same time.

Though this theory has been tested in various locations, none of them were in Sahara. This is why it needs to be tested in the field, hence the pilot. The sediment deposition is not of the same quality throughout Lake Nasser's 500 km length. The heavier, more gravelly sediments can be found upstream in the lake, at the point where the Nile enters the lake (in Sudan), and then gradually degrade in size and volume as it moves further down the lake. That is why the Sudanese part of Lake Nasser (Nubia) has lost 80 % of its live storage zone. But this also indicates that the best quality mud/sediments can be found in the deposits on the Egyptian side further towards the dam, as these are composed of the lightest and finest particles of organic and inorganic materials. This river of sediment flows slowly towards the dam but is still far away, which also had an influence on our choice of location for the pilot. The overall soil classification of the suspended sediments indicates:

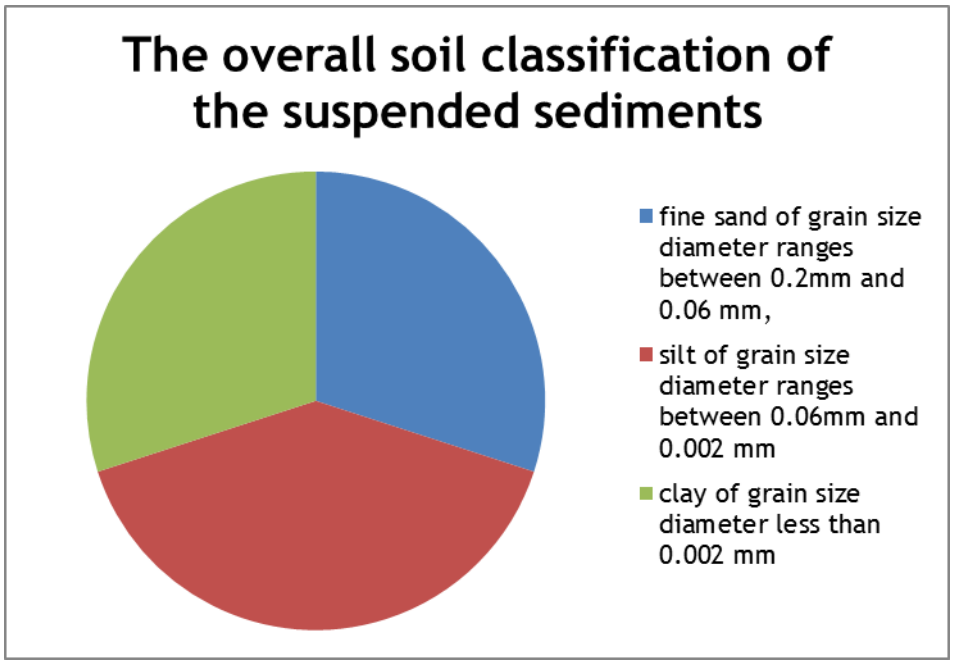

Figure 60. Soil classification of the suspended sediments, author

1) 30 % fine sand of a grain size diameter ranging between 0.2mm and 0.06 mm;
2) 40 % silt of a grain size diameter ranging between 0.06mm and 0.002 mm;
3) 30 % clay of a grain size diameter of less than 0.002 mm (78).

The quality and quantity of Total Suspended Sediments concentration (TSS) is affected by the size and type of suspended particles both inorganic and organic. The smaller and lighter the particles are, the higher the TSS concentration is. TSS is a major variable that is used to define the longitudinal patterns and sediment depositions in the lake. In this way, TSS affects light penetration, affecting the phytoplankton production. TSS in Lake Nasser is subjected to flood conditions and also varies from season to season and month to month. It is the highest from August until October and then starts to gradually decline until May or June, when the concentration of TSS (75) is at its lowest.

Third step: Dredging and solar-wind dredging ships

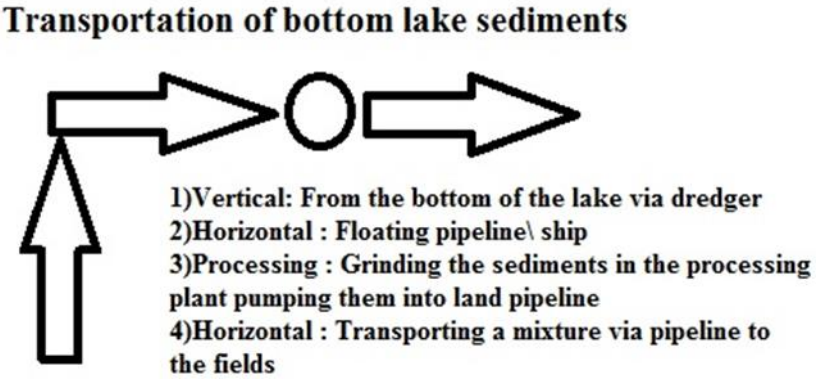

Figure 61. Dredging, author

The definition of dredging by Nick Bray (91) is that it is a subaqueous excavation of soils, rocks or minerals that consists of four phases:

1. Excavation
2. Vertical transportation
3. Horizontal transportation
4. Placement/use of dredged material

This technique has often been used to keep waterways navigable and is quite available and accessible across the world.

The area to be dredged is 70 km2. Bearing that in mind and knowing that the average depth is 30 m at the chosen location and the expected granulation (composition of dredged materials) should be of the fine particles of 0.2 - 0.002 mm we can conclude that this type of dredging activity should most likely be done with the cutter-suction dredger. This type of dredger has a hose that can rich depths of up to 30-35 m and can cut through sediments with the cutting mechanism at the suction inlet if needed, making it a reasonable option. First, grinding and milling of larger particles takes place at the entrance to the dredger's suction pipe, where all the larger pieces such as branches, leaves and other organic matter that got sucked in gets grinded, allowing for the more or less homogenous transport of the sediments.

Instead of using traditional fossil fuels to power our dredging ships we would like to experiment with a combination of sun and wind. Combining wind and sun energy for maximum efficiency should enable us to benefit from the geographical position of Lake Nasser and lower our project's overall emission of greenhouse gases. This type of ship would carry large amounts of silt to the floating pipeline or to the end storage facility. If necessary, small-scale lake mining could also be used, such as a High-Lift Dredge with a booster pump (92).

For the cargo ships we aim to use the already existing Japanese solar-cargo ship model. Since we are proposing a pilot project phase, it would be interesting to see if the budget allows for the implementation of new technologies in cargo-solar transport, as these are best combined with wind power and would allow us to lower our carbon footprint even further. Since this excavation, dredging and transport operations will be performed the Sahara, the effectiveness of such wind-solar ship will undoubtedly be great. Sun is the most powerful in Sahara and the constant wind presence is noted, from the direction of the Red Sea.

By using this kind of transport, we would produce a more sustainable solution with no use of fossil fuels in the entire transportation process.

Fourth step: End plant

Figure 62. The proposed locations for the end plant, Google maps, author

At the end, at the most southern location, which represents the main facility for further processing and transporting of the silt into the pipeline, all the silt gathered will be stored in a closed airtight environment to prevent high evaporation rates. The procedure of mud refining starts with the dredging itself and continues throughout the final processing in the end plant. In the end plant, silt will undergo a final grinding process and be directed to tubular settling basins before it gets to the special closed chamber with rotation platform, from where it will be pumped into the pipeline and distributed further onto the chosen location. The calculating of possible mud processing per hour gives us an estimate of 180 m^3 per hour for the initial plant, although this correlates with the size of the end plant and the amount of funds invested in this first phase. The benefits of using this kind of process will be far-reaching since it will not only provide us with savings in water and produce yet another irrigation solution, or use of dredged materials, but create a new, sustainable way to reclaim the land of the Sahara.

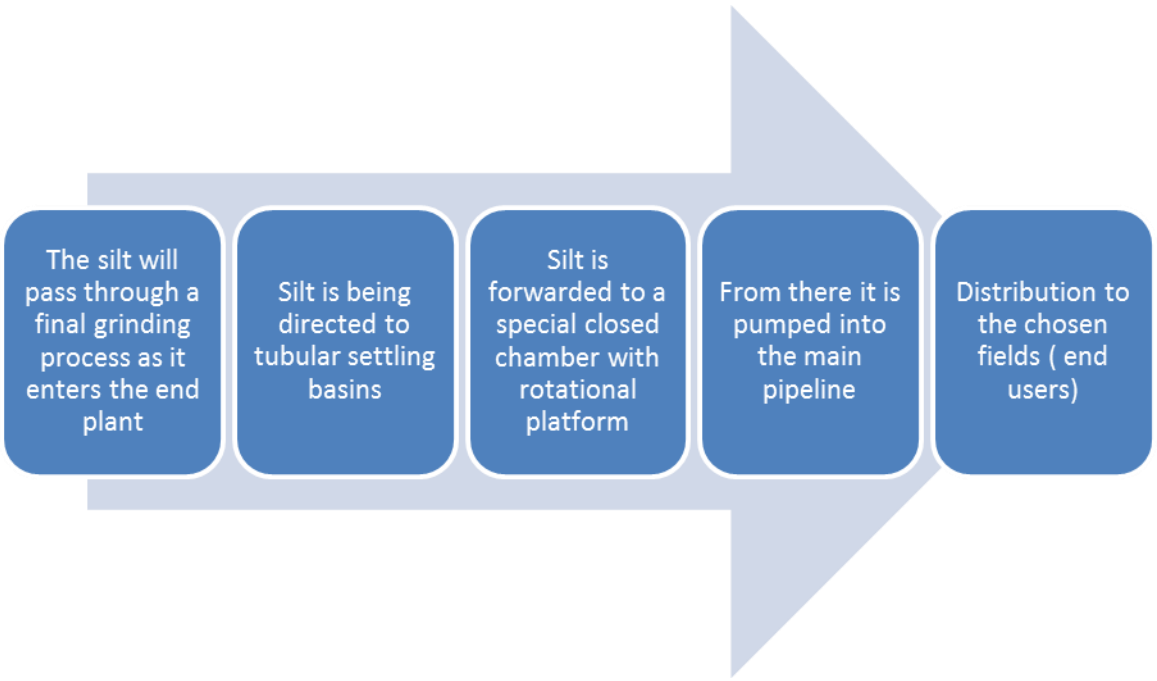

Figure 63. End plant processing, author

Fifth step: Pipeline for further transport of dredged sedimented alluvium
In this study we decided on the use of pipelines above all other alternatives such as ships, channels, trains, or cargo trucks because the initial costs for erecting the whole system and its infrastructure is lower than any of the above. We will achieve this by using High Density Polyethylene (HDPE) in our pipelines (which has pressure ratings of up to 1.1 MPa). Water loss due to evaporation will be kept to a minimum as the pipeline is a closed system. CO2 emissions will also be kept low, as the pipeline will not use any fossil fuels but the force of gravity and solar power when energy is needed, thereby avoiding pollution from fossil fuels.

Central to this approach is the accessibility of silt to the people and the pipeline system's easy manageability and interchangeability, which means that the pipeline can easily bring the silt to any remote village and can after a certain period be stopped and shifted to a plain irrigation system, or can be completely changed to a new direction, with the smallest of costs, as most of the parts would be simply reused. Pipeline systems could be designed and managed for the lifetime of the extraction site, giving us a comfortable method for using all proposed extraction sites at the desired times. The lower operating/maintenance costs of the pipeline system are also very important in the long run as 1 km of pipeline's average unit cost of total cost is $ 61/ft3 therefore 1km is about 2 million euros (93), with replacement being 250 % cheaper than one km of train tracks, which costs 5 million euros (94) and is 300 % cheaper than one km of asphalt highway (which costs 6 million euros (95)).

Transportation by Water / Land	Means of transporting the silt after dredging	Indirectly / directly mud transporting	Initial erection costs per one M€/km	Water losses due to evaporation	CO2 emission in grams per metric ton of freight and per km of transport	Manageability / interchangeability of the path without building new add-ons	Operation / Maintenance/ Replacement costs per €/km

W	Pipeline	D	2	0	<1	✓	/2,800-5,600/ 580,000
W	Ships	D	12*[4]	2-1	10 to 40	✓	>4000>1,000, 000
W	Channel	I	29.5	25x	10 to 40	-	>50,000
L	Motorway Cargo-trucks	D	6	2-1	60 to 150	-	5000*/178,00 0
L	Railroad Cargo-train	D	5	3	30 to 100	-	>100,000

Figure 64. Table chosing the means of transportation

For filling in the pipelines, we will use effective methods of dredging and transportation for silt. For this we need to know the quality of the mixture of water and sedimented mud, silt.

Rheology is the study of the viscosity of a mixture of chemicals or liquids and solids in order to appreciate the flow characteristics. The main characteristic observed in rheology relevant to our system is what type of flow it will have, Newtonian or Non-Newtonian. Newtonian liquids tend to have a normal, gravity-reliant flow while Non-Newtonian liquids tend to have an obstructed and unpredictable non-gravity-correspondent flow, which in our case could lead to blockages in the pipeline or worse, explosions under the extreme Saharan temperatures. At the moment no rheology tests have been carried out on the Nile alluvium-water mixtures, or precisely on the dredged bottom lake mixtures, to perceive the nature of its flows. However, there is plenty of evidence that the particles are sufficiently fine enough to induce non-Newtonian flows at high concentration. Many aqueous solutions with high/sufficient concentration of clay develop a Non-Newtonian flow in a mixture of dry content-water higher than 40 %. In the paper "De-silting Lake Nasser with slurry pipelines" the author B. Abulnaga proposes a mixture with a ratio of 40:60 silt to water when transporting the sediments. For our study we adopt the 40:60 ratio silt to water mixture. Depending on the expansion of the pipeline system, specifically in its m3/h/y capacity and further extensions through the Western Nile Valley, the process of the de-silting Lake Nasser or actual usage of the bottom lake sediment could take 25-100 years or more.

[4] *Meaning it does depend on the size of the ship multiplied by 10

* http://timeforchange.org/co2-emissions-shipping-goods co2 emissions

*http://www.dnvusa.com/focus/corrosion_materials_degradation/infrastructure/ costs

*http://ec.europa.eu/transport/themes/sustainable/studies/doc/2008_road_infrastructure_costs_and_revenues.pdf cost for motorway

*Trucks need a regular maintenance every 20 000 km plus the petrol cost for each km

With our logistical transport system, slurry pipeline and our planned additional 1 666 666.67 hectares minimum of new land, we hope to have a positive effect on the micro climate, which would eventually lead to a positive effect on macro climate.

Knowing this, is it not baffling that we will have 7 billion tons (80) of silt by the end of 2020, which could during the lifetime of our project provide Egypt with an additional 1 666 666 hectares of arable land with only the initial layer of 20 cm of silt coming from the bottom of Lake Nasser.

$$\rho = \frac{m}{V}$$

- ⇨ $V = \frac{m}{\rho}$
- ⇨ $V = 7\ 000\ 000\ 000\ 000 kg / 2100 \frac{kg}{m3}$
- ⇨ $V = 3\ 333\ 333\ 333.33 m3$
- ⇨ $Vf = 0.2 m3$
- ⇨ $A = \frac{V}{Vf} = 3\ 333\ 333\ 333.33 m3 / 0.2\ m3$
- ⇨ $A = 16\ 666\ 666\ 666.67\ m2 = 1\ 666\ 666.67\ ha$
- ⇨ Therefore 1 666 666.67 ha is the minimum amount of new arable land to be attained.

To simplify:

Vf= volume of silt needed for gaining 1 m2 of new arable land
T= 20 cm= 0.2m thickness of initial layer of silt
Silty soil $\rho = 2100 kg/m3$ consider 2700kg/m^3 by Baha Abulnaga (92).

We propose the 40:60 mud-water mixture as suggested initially in B. Abulnaga's research (78) as this relation is proven to have Newtonian properties in turbulent flows that appear while in pipeline transportation and it is therefore considered to be the most cost-efficient for transport. If we go higher in terms of silt, it would need more pumping energy to transport it, and that is just until the point of appearance of Non-Newtonian fluids, which will appear because of high clay content in the sediment. In terms of water, if we go higher than 80 % it would be a waste of water as it would not carry the needed amount of silt and therefore would turn into a simple irrigation project.

The minimum area that our project could reclaim is more than 1.5 % of Egypt's total land mass or 16 666.67 km2.

The design of the pipeline system alone is divided into three phases as mentioned above: the 1st phase, fully described in this paper, and the 2nd phase and 3rd phase. Important for all three phases are the fluid mechanics of the pipeline design. Ways to overcome inclines or get more potential energy for continuing the transport can be found in some basic rules of physics, application of all of these rules requires demanding careful and calculated planning to:

- ▫ Rapidly lower the pipe's height.
- ▫ Reduce the pipe's diameter directly in front of the turbine (this method could also be used to overcome problems which occur when there is a sudden rise ahead).
- ▫ Dig tunnels to overcome higher inclines. Or just use of tunnels

The pipes will have to be well-maintained over time. For this purpose, we will use robotics. The planned robotics will be a robo-vehicle which will be remotely operated and have brushes on the bottom and roller possibly on sides. The use of valves will allow for the placement of the robo-vehicle in the pipeline for cleaning it and at the same time monitor for any minor cracks or other malfunctions. Valves will be put in place every 1-5 km for smooth maintenance and easy repair/change.

The entire design of the pipeline system is highly adaptable to any conditions and very reliable for transporting through desert liquid of any kind. The added bonus is the possibility to disassemble and reassemble the pipelines reusing nearly all of the old parts, which allows us a good fit in the global agenda of reduce, reuse and recycle.

Sixth step: New arable land
New arable land is our aim. These new fields will be designed to best suit the surrounding area. We will produce mainly three different kinds of fields in this part of the Sahara, these will be:

1) Classical quadrangular-shaped fields
2) Circular-shaped fields, like in the Toshka area
3) terraced fields

The choice of which type of field to use will be taken according to the surrounding terrain, meaning that they will be used accordingly as the pipeline system goes deeper into the Western Desert.

After the field has attained its predetermined level of silt content, it should be cut off from the silt pipeline and supplied with irrigation, which will follow the silt pipeline in the form of a separate pipeline. The design of the irrigation and silt transporting system will be a drip one, except in terraced fields, where the fields themselves will be used for the deposition and spreading of the excess water farther down the hill. All of this will have to be planned with botanical and agricultural experts at each particular location, as different locations will require different cropping regimes as well as irrigation.

Seventh step: Vegetation [5]
A very important part for the development of our work is choosing the correct plants. We therefore propose to follow the path cut by the following successful afforestation projects:

1) Turning Deserts into Forests, Morocco
2) The Keita Integrated Development Project, Niger
3) The Sahara Forest Project, Qatar and Jordan
4) Sundrop Farms, Australia
5) The UN Billion Trees Initiative
6) Keren Kayemeth LeIsrael-Jewish Nation Fund, Israel

Through adopting already proven practices that work in the field, planting species that have been proven to flourish in the desert sun, and combining this with a Permacultural approach we will achieve the desired results. The plants that are to be grown in the next 20 years should therefore be carefully selected based on the properties sought:

[5] Fully explored in chapter Introduction to Agroforestry below.

easy adaptability to the desert; or native to desert plants; resistance to moderate salinity (or ability to thrive on it like most of the *Limonium* family or similar species); ability to leave certain good minerals in the soil after them; reduced water absorption; and potential to fetch a good price on the market. We should use different methods while planning which species to plant, and consider using intercropping and agroforestry integrated with the Permaculture as one of the main agro-forestry approaches to afforestation, in order to produce a healthy and sustainable soil. Some of Africa's native plants like the Moringa genus, have very high drought resistance, grow into trees/shrubs 12-15 m high, and have a high market value, all of which makes them a perfect candidate for this specific agroforestry project. The main goal is not to just irrigate but to produce quality soil, to add an additional 20 cm of soil on top of the basic 20 cm of silt that we would provide via pipeline. This could only be achieved by having complete control over planting and crop rotation, and would allow us to use some of the old techniques such as the ancient Egyptians" use of clover and the nitrogen it produces to improve the quality of very poor land. Economically valuable agricultural plants should tip the balance when deciding. The stages of growing (planting) the fields in order to achieve better yields of soil will be:

1. Annual plants (in the 1st year)
2. Biennial plants (from the 2nd year on)
3. Perennial plants (from the 1st year on)
4. Controlled mixture of annual, biennial and perennial plants (from the 5th until the 20th year)

Eighth step: Growing soil

Planned growth of soil in the next 20 years has to be closely and constantly monitored if we are to have successful controlled agroforestry in 100 years, after which time we should have a self-sustained agroforestry system that should be able to take care of itself. At that time, we can assume that the Sahel will prevail over the Sahara, causing a shift in micro climate that will lead to a positive shift in the macro climate. To achieve this, we will have to use multiple levels of soil protection. In the first years of the project, in order to protect it from the Sun and prevent overheating and high evaporation rates which would lead to salinisation of the soil, solar panels will be used as Sun protection and they may also provide protection from the windblown sand. Sand and wind will be our greatest obstacles during the coming years, therefore to prevent sand accumulations form sand storms and further enrich the soil with nutrients we should focus on Permaculture with agroforestry and intercropping as secure options.

Using trees, especially those adapted to these conditions and which are fast-growing, like those of the *Moringa* family, could be one of the most reasonable solutions. Trees would provide shade, protection from windblown sand, nutrients and also be very lucrative for the villagers (100g of dried *Moringa Oleifera* leaves costs more than 10 euros in Austria, for example). This particular species is also highly attractive due to the fact that all of its parts are edible (it has been pronounced the tree of the 21st century by the FAO; a tree that can end malnutrition) and when grinded its seeds can be used as a natural water purifier compatible with conventional ones used in the developed world (96). There are many uses for this tree and one of the most important ones is that it empowers the farmers directly, as observed in Niger, where on average the farmers" revenue saw an increase of 298 % (97) solely on the basis of planting Moringa trees. Trees and shrubs should be used as a fence to protect from sun and sand, as soon as they reach a satisfactory height.

Ninth step: Solar panels
These specially designed solar panels will be semi-transparent, robotic and coated with special materials able to catch water vapour. They will be used primarily as the first line of defence against the harsh Saharan climate. They will provide a triple line of protection. First, they will be used as sand blockers, acting as shields, they could be programmed to react when a sand storm is coming and rearrange themselves into a protective formation and keep our hard-earned soil from turning back to sand. Secondly, they should be used as sun protection, being semi-transparent and made so as to be adjustable to sun and take in as much of the Sun's energy as possible when it is at its highest peak while allowing the plants to use the sun when it is weaker, in this way protecting the plants from frying in the desert sun but still allowing them to use the sun for photosynthesis. The solar panels" third use will be to collect evaporation using their specially designed surface, and allow us to reuse this for irrigation purposes.

Tenth step: Planning extensions
Through carrying out additional analyses, we will be able to plan the infrastructure initially needed for the 2nd and 3rd phases. By connecting the existing oases to each other and to the Mediterranean coast in order to make the New Valley possible, we will also be creating new habitats, new houses, new villages, new jobs, and new opportunities in arid, remote areas of Egypt, while at the same time afforesting the Sahara and taking one of the first steps toward geoengineering the climate in the hope of stopping global warming. This could also serves as a model for the new self-sustained, green-powered village of the 21st century.

What this project offers is a possibility for new windmill power parks to be built in the Aswan region. The map of winds indicates strong wind from the south-east in the central eastern part of the lake. Winds that blow in this region are making dunes and blowing sands into the lake and just adding to the sediment problem.

Sustainable analysis of the project

The Brundtland Report coined the phrase "sustainable development" and defined it as: meeting the needs of the present without compromising the ability of future generations to meet their own needs (98). Although this can be viewed as a utopian statement, it has already been put into the text of the EU Sustainable Development Goals (99) and the UN Sustainable Development Goals. Our project strives to accomplish this and more, as leaving new arable fields should be considered as part of a beyond sustainability approach and that is something we should all strive to if we wish to help and preserve our planet's complexity, climate and biodiversity for future generations.

So in this phase we can only be responsible for the consequences that our own research will leave. Calculating the consequences in this way and with a low carbon footprint and adoption of the green energy sources for supplying the electricity we will try not to disturb the environment any further than it has already been. By carrying out an Environmental Impact Assessment, we can see exactly see how our project will affect the environment. We aspire to make a positive change to the microclimate, provide new employment opportunities and provide more arable land, and thus more food, for the ever-growing population of Egypt.

In the long run we aim to produce a cultivated forest in the midst of the Sahara Desert to connect areas of green from oases to the Nile's shores and the Mediterranean coast. In this way the microclimate will develop better and come to look like the Mediterranean coastline in Egypt, Libya, Tunisia, Israel, Greece, Montenegro, Croatia or even southern Italy. The fields will gradually start to be covered with lucrative palm

trees and allow the crops shade and protection, effecting the winds in local areas, making them rescind, and finally, in 100 years, effecting the global climate to lower temperatures.

Thus, this project needs not just the correct implementation but also the support of government in handling the project, which would provide, together with the World Bank, financial support and educate people, especially children of a young age, about the benefits of sustainability and afforestation through Permaculture, as sustainability involves not just physical and environmental adaptation but psychological adaptation as well and the direction of adaptation can be influenced by family, formal education and information services.

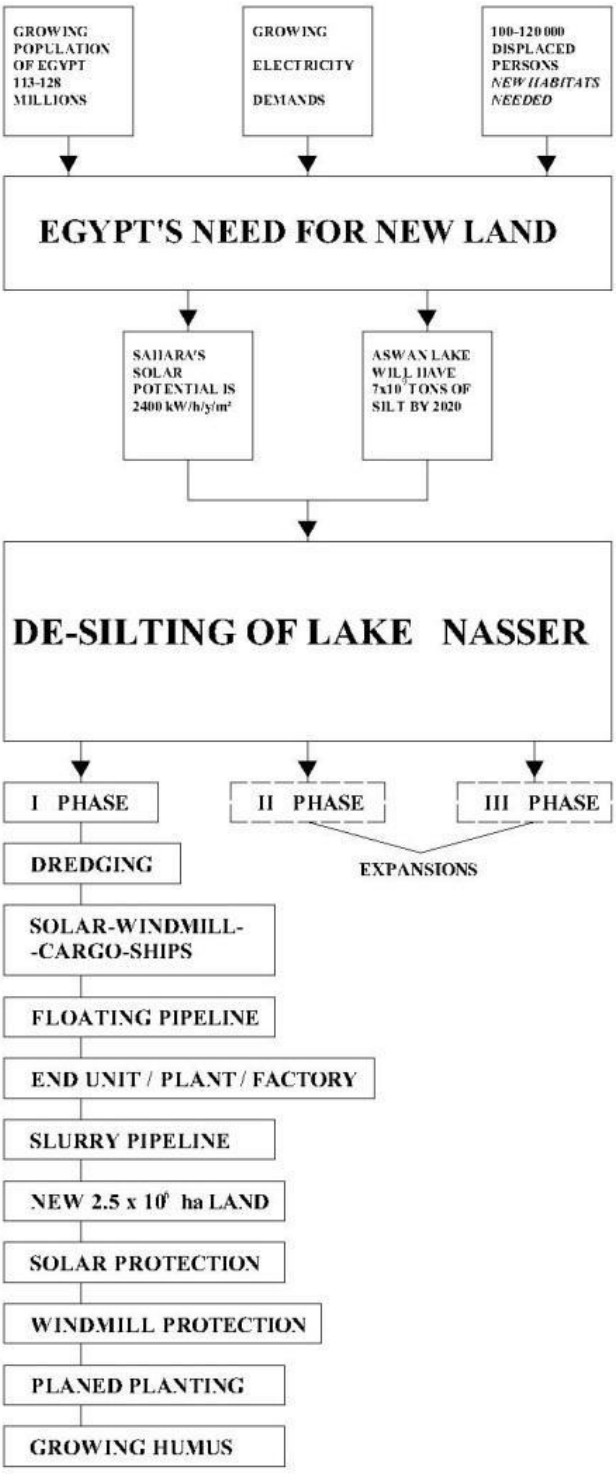

Figure 65. Overall scheme for the first phase, author

Conclusions and contributions/recommendations

This research can be defined as a multidisciplinary approach to the development of new rural/urban areas in arid Saharan regions. By further development of this project and similar projects we can contribute to the decentralisation of North African countries that are in danger of becoming even more overpopulated in the next decades, in the case of Egypt even though a vast amount of its land is unoccupied. Developing new ways for gaining land from desert, water and green energy appears to be the right choice as the problem of rising silt is emerging not just at Lake Nasser but in more than 50 % of the world's alluvial artificial lakes (77). Solving this one problem could potentially lead to new discoveries in the design of future alluvial river dams which would prevent initial

capture of the silt, and may also lead to new possibilities in pipeline design, new views on exploiting the solar power of the Sahara and all other arid and hot regions.

Our project also has the potential to give us new insight into solar rural electrification (which is seen today as an effective instrument for the sustainable development of rural regions in developing countries) and into the new design of sustainable transport and urban development, since the final aim of the project is the unification and expansion of all green areas in Egypt, which in turn will lead to the development of new habitats, new regions, new connections, new roads, and railroads.

Introduction to Agroforestry

To comprehend fully the benefits of afforestation and reforestation, one must first entirely understand the extent to which the deforestation is harming the global population, Earth's soils, and biodiversity, while pushing the Global Climate Change into the irreversible direction of Climate Change.

Deforestation, afforestation and reforestation

The Earth's land mass has a forest cover that is approximately 30 % *of mainland*. On mainland 30 % of land is covered by forest. Deforestation that occurs annually is tracked by UN FAO to be around 13 million hectares per year (100), which is nearly the size of Greece. We have already lost 3 % of Earths forest cover due to deforestation (101). Even though small percentage, when seen in kilometres square as 1 350 000 km2, its significance as a carbon sink rises instantly; knowing that the old-growth natural forests do not only store carbon dioxide in its biomass, dead wood and litter, but in its soil as well, the importance of its preservation elevates. The relisted carbon dioxide from deforestation is great, and it is observed that the total amount of deforestation throughout the world contributes to 20 % of global carbon dioxide emissions, which is more than total EU greenhouse gas emissions *a striking fact* (101).

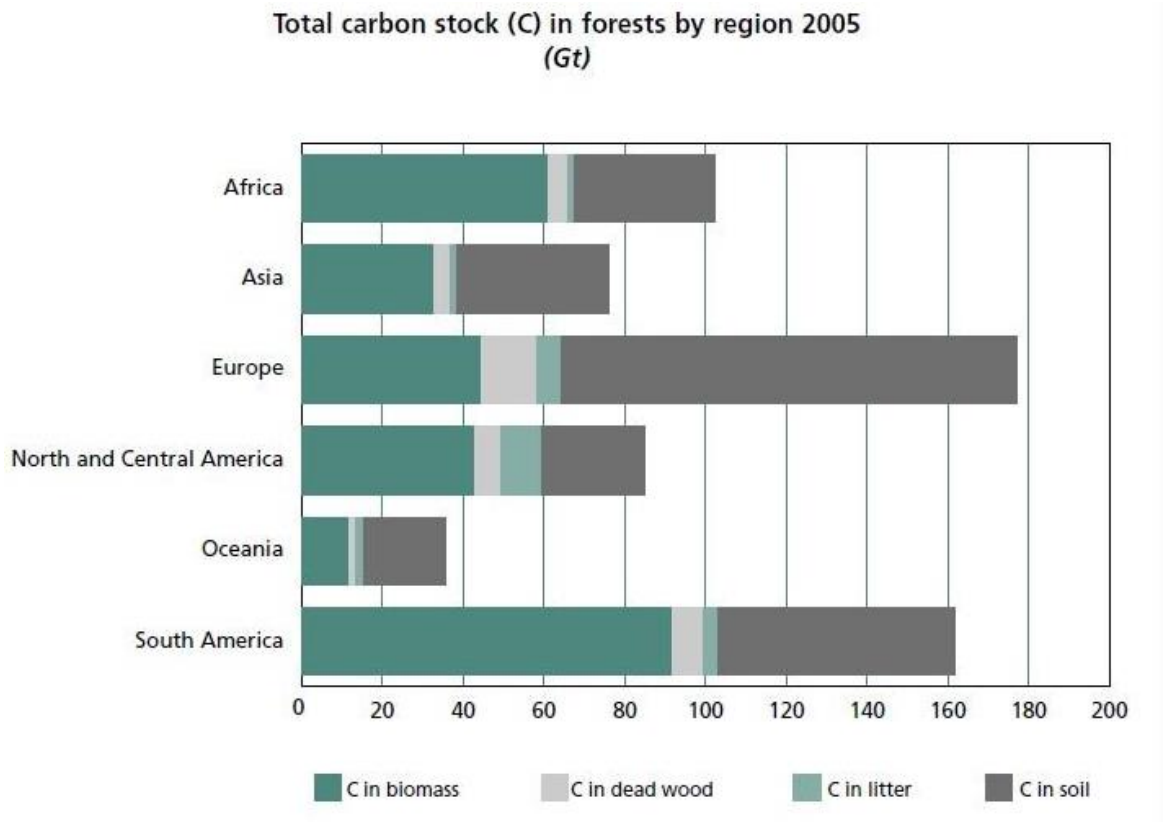

Figure 66. Carbon Stock in Forests by Continent (102).

The negative impacts of deforestation can be seen in environment, thought climate change, biodiversity loss, soil erosion, soil degradation, landslides and increased likelihood of natural hazards such as storms, floods, and extreme fluctuations in weather conditions in general. The greatest amount of deforestation has happened mainly in tropical and subtropical forests, 96 % of the recent global deforestation, where more than 70 % of the world's species are found. Its negative effects can be observed in society as it threatens the lives and livelihoods as well as culture of people that relay on forest and non-timber forest products and can therefore be felt in economic terms too.

Deforestation is defined by the European Commission as: "Deforestation refers to the destruction and conversion of forest land to other land uses usually considered more profitable. Forest degradation is used to mean the destruction of specific aspects of forests such as a decrease in tree cover, changes in their structure or a reduction in the number of species that can be found there." (101).

Due to wide variety of factors, most predominantly human deforestation, together with global climate change, forests need human help to re-establish themselves, these efforts are widely considered either reforestation or afforestation projects. To be able to determine which of these two we are referring to, we have to be able to define them adequately first.

Definitions of afforestation and its difference from reforestation has long been a focus of on-going debates, such as the one described at IPCC (Land Use, Land-Use Change and Forestry| 2.2.3. Afforestation, Reforestation, and Deforestation)[6]. This study will not go into them, it will accept and acknowledge the definition given by Food and Agriculture Organization of United Nations by which: Any project can be considered an *afforestation* one, if it can give proof of prior land use and so that the land being utilised for the project was not forested for at least 50 years. FAO UN also defines what forest is "Under the Clean Development Mechanisms (CDM) of Kyoto Protocol, "forests" consist of trees with at least a height of between 2-5 m, crown density between 10-30 %, and area between 0.05-1 ha. Countries must choose values for these parameters and determine a minimum width of a "forest". Since the Protocol does not define "tree" 2; fruit trees, bamboos, and palms may qualify. Afforestation and Reforestation can consist of assisted natural succession to trees, productive and protective plantations, agroforestry, and urban forests. For purposes of CDM, trees in a landscape may or may not reach the chosen threshold for crown density of a "forest", depending on crown cover and project boundaries. Enrichment planting in degraded forests or forest rehabilitation does not qualify as "reforestation"." (103). On the other hand for a project to be considered as a reforestation project, it has to give proof that it was converted to other uses other than forest before 31.12.1989. (103).

Considering all that has been explained so far, this work does not argue that deforestation is in any way justified as long it has been replenished, substituted by plantations of cultivar trees, nor does it in any way considered that the great losses suffered through any deforestation could be annulled by any afforestation or

[6] http://www.ipcc.ch/ipccreports/sres/land_use/index.php?idp=47

reforestation projects in any way. The author is of strict opinion that forest preservation and constant renewal and growth of world's canopy through preserving the remaining old natural forests accompanied with different afforestation and reforestation projects is the only way our generation could leave any positive mark on this planet. First preservation and second planting the new growth.

A relatively new field of science that takes particular interest in afforestation efforts is called Geoengineering. Geoengineering is defined as the deliberate large-scale manipulation of environmental processes that affects the earth's climate in an attempt to counteract the effects of Climate Change. Afforestation is considered to be one of many geoengineering techniques to combat Climate Change, is well established in this field and advocated for.

Following the definition of afforestation given by FAO, whit simple but strict guidelines, it can be determined that the methodology described in this PhD thesis will fulfil the requirements given by FAO, and can therefore be referred as a method for afforestation of the Egyptian Western Sahara Desert.

Examples of successful afforestation projects around the World and their relation to this one

"Trees and humans are in an intimate relationship. What they exhale, we inhale, what we exhale, they inhale. This is a constant relationship that nobody can afford to break or live without." – Sadhguru (104)

Forestation, next to a form of Biochar, was used in agriculture for the longest period of time in order to bring up the nutrients in soil, stop erosion, provide shade and many other different ancient uses, and since the 20th century afforestation has been used as geoengineering approach to prevent and mitigate the destructive effects of Climate Change.

There are numerous afforestation projects across the globe worth mentioning here; this study will focus on those which methods, approaches or initiatives could be implemented in desert greening. Amongst all these noble projects, that will be described in the following chapters there are a few that stand out, may it be because they were led by a single individual with a big dream, or because of their great achievements, but they are worth pointing out separately nevertheless. The most inspiring one is most defiantly NGO Oceanium, in Senegal with Haïdar El Ali, as a front man, and their 30 million saplings in 400 villages in 2009 (104). Other impressive individuals and their NGOs include, Sebastiao Salgado and his wife Leila, with the NGO Instituto Terra, in Brazil, and their admirable achievement to bring back the deforested rain forest on 700 ha, which now nourishes 1.5 million trees (104). Then there is Sadhguru, an Indian yogi, and his Isha Foundation, with planted 850 000 trees in just three days in 2006, and projected 114 million. Another notable individual Paolo Lugari, the founder of Las Gaviotas, an eco-village in Colombia has reforested 8,000 ha which resulted in 10 percent more precipitation now (some 110,000 m3 per day)[7].

Other relevant afforestation projects to this thesis work from across the world are the following:

[7] http://www.zeri.org/ZERI/Reforestation.html

1) Turning desert into forest, Morocco (105).

This project has been developed by a not-for-profit corporation, Turning Deserts into Forests, Inc., predominantly on two locations, in South Africa and Morocco. This project focuses mainly on the application of gel water to sustain the plant for a prolonged period of time in arid and hyper arid conditions. Their success is well documented, although they focus mainly on agro-forestry systems, planting various vegetables in deserts and hyper arid regions, with spontaneous trees, such as Paulownia Tree, Jatropha Curcas, Moringa Oleifera, in different planting schemes. Their choice of trees is very good, as these are all fast-growing trees and Moringa Oleifera can tolerate drought. Considering the location of their already successful project in Morocco and its closeness to the location of this study in Egypt, the choice of their carefully picked plants is important to this project, for the same plants, which have great economic exploitation possibilities, could be planted in the New Valley of Egypt (105).

2) The Billion Tree Campaign, across the globe by UN

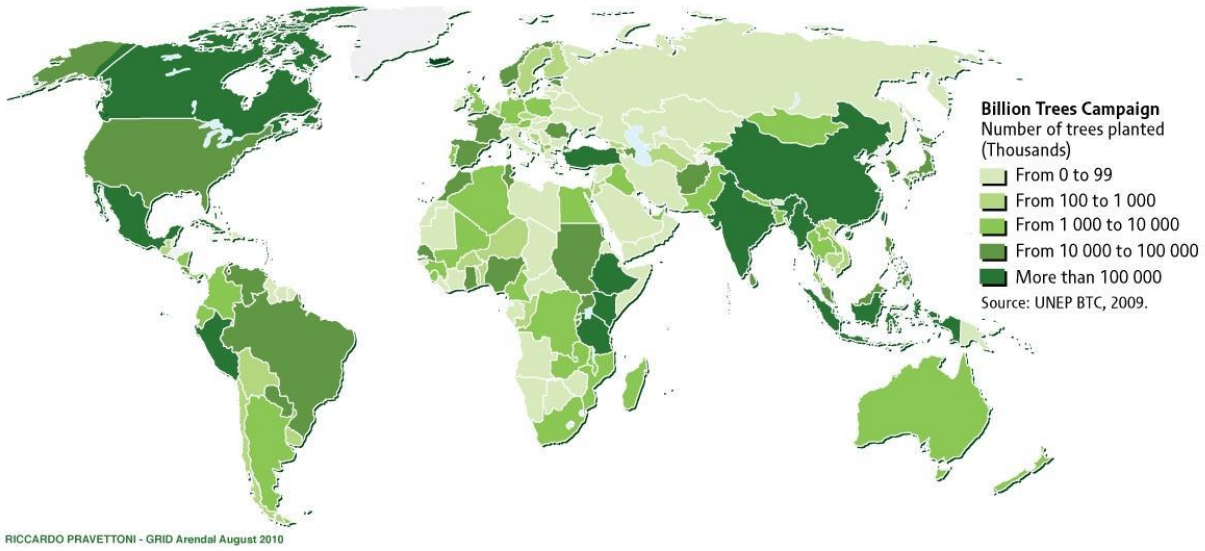

Figure 67. The map of the world as seen through the eyes of the Billion Tree Campaign; free downloaded from their website (106)

This great initiative was inspired by Professor Wangari Maathai (Nobel Peace Prize laureate for 2004 and founder of Kenya's Green Belt Movement, which has planted more than 30 million trees in 12 African countries since 1977). The goal was to inspire and engage ordinary people, communities, businesses, schools and educational institutions to make a pledge over the official website in planting trees in their local communities. This map represents the sum of their pledges and the overall number during the first five years of the campaign, of 12 585 293 312 trees that were planted and registered on the Billion Tree Campaign website. The website encourages people to make a pledge anywhere from single tree to million trees, to always plant indigenous trees and ones most suited for the environment, for what they have provided guidelines as well as the possibility to get locally tailored advice, such as from the World Agroforestry Centre (ICRAF). Using locally sourced trees and focusing on native and indigenous plant varieties that do not require excessive irrigation, is the focus of this study in Egypt too, hence the importance to reflect upon it. The whole campaign grew into a foundation, which is governed and receives advice from an advisory council, consisting of Founding Partners: The Green Belt Movement, The Prince Albert II of Monaco Foundation, the

World Agroforestry Centre (ICRAF), the UN Food and Agriculture Organization (FAO) Forestry and the United Nations Environment Programme (UNEP). (106)

One aspect of this great initiative that can be incorporated in other af/re/foresting projects worldwide is a global local involvement. Engaging people on global level to make a pledge and then see it through on the local level.

It would be interesting to see how a similar platform developed for Egypt could engage people with interest in Egypt or interest in afforestation of the Sahara Desert, like the diaspora of Egypt, or scientific communities, Egyptologist societies and similar, from all over the world to pledge and plant more trees in Egypt. They could make pledges over the new platform, and/ or donate money for a sidling or planting the tree themselves on their next visit to Egypt.

Another project that comes right up is:

3) Jewish National Foundation JNF, Israel (107)

Jewish National Fund is a non-profit organization founded at the Fifth Zionist Congress in Basel, Switzerland in 1901, as founders two names are mentioned, Theodor Herzl, a Viennese journalist, inspired by an unjust trial that he had witnessed, and a German Jewish mathematician, Zvi Hermann Schapira, who was the first to suggest to use the found to buy land in Palestine. First lands were bought in Judea and the Lower Galilee. *The JNF played a central role in the founding of Tel Aviv, in 1909.* The establishment of the "Olive Tree Fund" was the beginning of Diaspora support for the afforestation projects. The Blue Box, known in Yiddish as a pushke, has been part of the JNF since its inception, symbolizing the partnership between Israel and the Diaspora. (108) Jewish National Fund (JNF) has been criticized a lot concerning the afforestation of Palestinian refugees" villages, West Bank, confiscating the land and afforesting the abandoned Arab villages in late 50's. However recently they have donated 3000 seedlings of trees for the Palestinian forest project. Namely this great foundation, no matter the political background, has made its mark on the environmental plain of this earth. Over the past 114 years, JNF has planted more than 250 million trees, built over 240 reservoirs and dams, developing over 250 000 acres of land, creating more than 2 000 parks, providing the infrastructure for over 1 000 communities, and connecting thousands of children and young adults of diaspora to their heritage. (107)

The mastery of their development is admirable, and not just by looking in their achievements, as they have made Israel one of only two countries in the world that had entered the 21st century with a net gain in the number of trees, but also in their approach to fund raising and especially in their development of the connection between the diaspora and Israel, form which example lots of countries could learn from.

JNF deserves a special chapter in any book related to afforestation as they have truly set the path for rest to follow; unfortunately, here it is just briefly mentioned with a focus on their great practices and the possibility of their implementation in Egypt. Yet they have made their fair share of choosing the wrong plants and non-native species which had resulted in death of many trees, and some not so successful parks and forests, but this was long time ago and it's good that it is in our history books so that we can learn now from their practical examples and experiences. On the other hand, JNF has given us a great number of successful ones especially in the area of the Negev desert; the afforestation project that is the one most closes to the Saharan conditions, and let us not forget that the whole state of Israel was a desert just one hundred years ago.

Today JNF focuses mainly on planting trees indigenous to the Middle East such as native oaks, carob, redbud, almond, pear, hawthorn, cypress and the exotic Atlantic cedar, trees that would undoubtedly flourish in Egypt too. Organised, state supported, well founded management of an afforestation project is a guarantee for success in any country. The various elements of fund raising, attributed to very good management, are exceptional. Even today on their website among other options sold there to promote afforestation, water security and fire prevention, one can find a button "Plant trees in Israel", leading to a link on which you can find different options and occasions in which to donate a tree, or 10 trees saving money that way, just simply brilliant. Making a bond between the Israel and diaspora ever so strong, and this is, brought out in so many different things that they do, it was so perfected over the years, that any country could learn from various project they have successfully completed thanks to the help and involvement of their diaspora.

JNF is an institution from whose planting, planning and pioneering mistakes we have and we can still learn a lot from.

The next project that relies on the support of communities, in this case local communities is this one:

4) Keita Integrated Development Project, central Niger

The Integrated Rural Development Project in the Ader Doutchi Maggia, Niger (PDR-ADM) that is better known as Keita Integrated Development Project was founded by Italian government in 1983 with great support coming from the United Nations. The last phase that has started in 2003 is being run by the UNDP. As of September 2009, the Project has cost approximately US$88 million, with the majority of funding (US$66 million) coming from the Italian government (109). The reasoning for the development of this project was to reverse desertification in the Ader, Doutchi and Maggia valleys of Keita Department, in the Sahel region of Niger and with it to assure food security, which would eventually lead to the reduction or stop of mass migrations from these regions to Italy. The impact of PDR-ADM interventions on the environment has been monitored by a multi-temporal analysis of land cover. Changes in land cover are the result of synergies of different factors (climate changes, interventions of PDR-ADM and demographic pressure).

The environmental status before the beginning of the project testifies to the negative impact of climate and anthropogenic pressure on the ecosystems. In 1962, the slopes of the highlands were forested but in 1972 some signs of degradation started to be evident until 1984 when the forest completely disappeared. Between 1984 and 2002, a progressive recovery of the natural vegetation has appeared by helping to develop better living conditions in Niger thought afforestation, land reclamation. Thought the human pressure is still big and the migrations towards Italy have not stopped the overall achievement is: reclamation and improvement of agricultural and pasture lands, reforestation and dune fixation is 34 483 ha, while they have planted nearly 20 000 000 million trees. This is one of the longer lasting projects, from which history it is worth learning from.

The inclusion of local communities and their involvement in the afforestation and reforestation projects is one more, great, example of a local-global thinking methodology. By helping local communities built their life in more secure way, focusing mostly on food security, the project had a global approach, first in stopping the desertification process and afterwards engaging in reforestation and afforestation projects all in aim of providing food security thought agroforestry.

There are several projects worth mentioning for their high-tech involvement even though they cannot be seen as afforestation projects their efforts in bringing life to desert and their technical innovations/ improvements are worth their mention. They are also very important as for their marketing objectives; that have been realised thought the course of the big investors, big business, and with support of some world renounced institutions they have made their project a commercially viable one to start with like:

5) Seawater greenhouse (110)

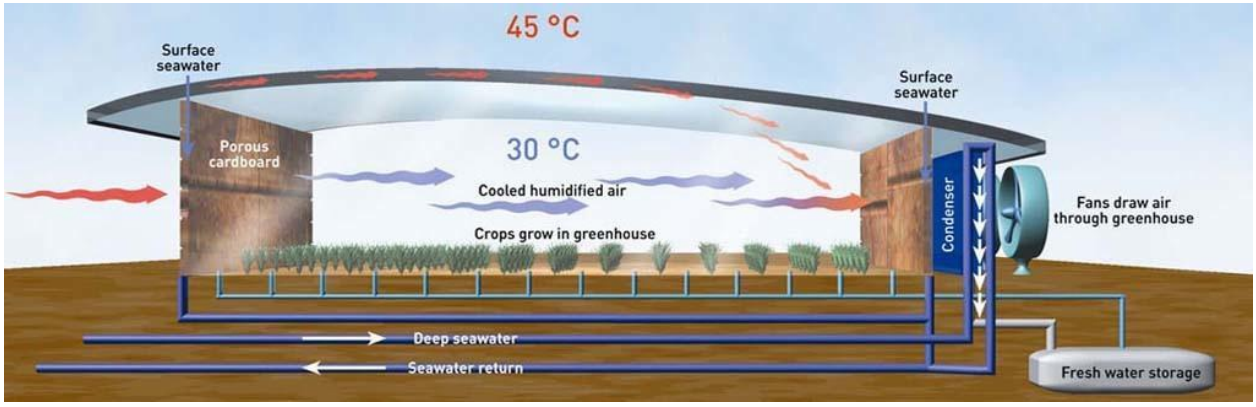

Figure 68. The concept of using the sea water for desert agriculture developed by Charlie Paton 1991 (110)

Using the seawater to cool the air temperature in glasshouses while producing fresh water in the process was first researched and developed as an innovative design concept by Charlie Paton's company Light Works Ltd, now Seawater Greenhouse Ltd in 1991, on the Canary Island of Tenerife. A first prototype named "Seawater Greenhouse" as the company's name today, was assembled in the Great Britain and then later constructed on the site in Tenerife. The pilot project proved to be a success and the Charlie Paton dedicated himself and his career to it, even today he is working on perfecting the system and making the production of vegetables and crops in the hot deserts ever so better. The main benefits of supporting and using such systems are in the conservation of freshwater resources, as the system makes its own from sea water by desalination process that is pure and distilled with no need for any extra chemicals, it reduces fossil fuel use, as it uses sunlight for any thermal change needs that arise on the farms, lower operating costs, as electricity and water bills are taken care off, efficient use of otherwise unusable land, fewer "Food Kilometres" especially in Arabic peninsula, creation of Green Jobs, reduced pesticide use, and by supplying us with naturally delicious and sustainable produce.

Today Charlie Paton's company is working across the globe making new seawater greenhouses that are very successful, such as ones in Abu Dhabi and Oman or Australia. There are two of his projects that are of interest to my research due to for their location and new implemented technologies; Charlie Paton is the co-founder of both.

a. Sundrop Farms, South Australia (111)

The similarity with his previous projects is great and there are very few differences, as this one was initially founded as Seawater Greenhouse Australia, which was established in 2010 as a joint venture between Seawater Greenhouse Ltd and Saumweber Holdings Ltd. With effect from 28th February 2011, it became a fully-owned subsidiary of Saumweber Holdings Ltd. (110)

The main advancement/improvement that can be observed in this system is in the use of hydroponics within the glasshouses. Hydroponic systems are however observed as early as in famous gardens of Babylon, but the symbiosis of the seawater greenhouse and hydroponic system is a novelty and a great example of sustainably managed resource one with promising results.

b. The Sahara Forest Project, Qatar and Jordan (112)

The Sahara Forest Project was developed as a brainchild of Charlie Paton, Michael Pawlyn and Bill Watts (113), now a foundation dedicated to promoting growth of agriculture where it would have otherwise been impossible. The project focuses on combining the different technological advancements proposes the use of sea water in low desert lands of Qatar and Jordan, with an interesting biomimicry approach that heavily relays on human control and monitoring for any future success, it is in essence an improved first Tenerife version of Charlie Paton's seawater greenhouse with some boosted functions. From their own observation: "The three core components of the Sahara Forest Project are saltwater-cooled greenhouses, concentrated solar power (CSP) and technologies for desert revegetation," technologies for desert revegetation are rather obscured and none existent (112). The whole system will be relaying on synergies coming from the technologies integrated into low-waste interconnected systems to improve performance of those with the individual components as well as the economic performance. The synergies between the technologies that are listed on the website of the project are the following:

a. CSP needs a supply of demineralised water to keep the mirrors clean and to run the turbines
b. The greenhouses are effectively acting as cooling towers for the CSP and get rid of the excess heat.
c. The CSP mirrors make it possible for a range of plants to grow in the shade underneath and, if the mirrors were placed immediately behind the greenhouse, it could extend the zone of elevated humidity behind and consequently promote more restorative growth
d. The new outdoor vegetation stabilizes soil and reduces dust so that more sunlight reaches the mirrors of the CSP installation (112).

None of these technologies are individually extremely relevant to this research, but are worth mentioning as the holistic approach they have adopted together with the proposed biomimicry is very significant. Biomimicry approach is the main premise of this research.

6) Desert Control patented system (114)

This system is in essence soil amendment, not a system for stopping desertification or deforestation. It has been developed by Ole Morten and Kristian P. Olesen together with Andreas Julseth, since 2008. The product is Liquid NanoClay (LNC). It is produced by combining clay and water in a patented mixing process.

The process is described by the founders as follows: "We bring our patented mixing units to the customer and apply LNC directly into the irrigation water and use sprinklers to spread it. The mix sinks into the soil, creating a 40-60 cm deep layer, which retains the water like a sponge. This layer stops water from evaporating and ensures optimal growing conditions for anything you plant in it." (114)

Their whole product is something that Egypt naturally had, and this is why it is very important to mention this product as the sedimented alluvium mixture, which my

research focuses on, naturally already contains 30 % clay which is why it was originally making the Nile valley so fertile for years after one flooding season. The observations and findings gained through their research are of great value to this project as they are a positive example of planned techniques that we want to achieve especially in biomimicry.

From the conversation with founders, and their personal experience in the field, LNC is a very costly soil conditioner not applicable to many locations. Aside from costs the LNC has to be applied annually depending on the irrigation type and agriculture used, very much like the annual river basin flooding, which further increases the costs, and if observed with annual crops like wheat it is altogether too costly to use. The best use of LNC could be in Permaculture or agroforestry or any type of forestry, where it will be used as a single application for soil conditioning and then left to nature while not being watered down with constant irrigation.

Amongst all these projects and many other that could not have been mentioned here, that are focused in reducing deforestation and desertification across the world one has to be given special attention here as for its location and the role it has played in starting and development of this research. That is the Toshka New Valley project in Egypt.

Toshka project as a special approach to developing the "New Valley" of Egypt

Figure 69. Photo of irrigated plots between the Lake Nasser and the Toshka Lakes (115)

Toshka, Tushka, Toschka, New Valley, and many other names that appear through literature addressing the Toshka Wadi region, I will be using the name Toshka, as it was the most common in the available English literature) New Valley development project is a set of government run initiatives and operations that produced a massive irrigation venture in the Toshka Wadi depression.

Location

The Toshka New Valley project is located in the former Toshka Wadi, which lies above an Eocene limestone plateau formed in prehistoric times that now represents a group of access water lakes or the Toshka lakes, in the south of the country west of the lake Nasser. In order to lower the water level and release the pressure at the Aswan High Dam, the Egyptian government decided to develop a system of canals that would carry the water from the Lake Nasser to Egypt's Western Desert, Toshka Wadi. The lakes were formed at Khor through the manmade Sadat Canal, the building of which started in 1978. This canal was meant to lower the pressure on the Aswan High Dam (AHD) and release the water from the AHD reservoir at very high water levels such as 178 m AMSL or above, which enabled for the development of the New Valley Toshka project. The formation of the lakes started 1998 as the astronauts recorded seeing the eastern most lake, as the waters continued to be high all the lakes were forming shape and the last one to develop was in March 2001. The lakes are to this day unnamed individually, but are called the Toshka lakes as a whole, their maximum surface area is 1 500 km^2, holding about 5×10^9 m^3 of water (116).

Geological history

Underneath this Eocene limestone plateau and underneath the bigger part of the Western Desert lies the Nubian Aquifer, which is one of the world's largest aquifers covering $2x10^6$ km^2, it spreads across Sudan, Libya, Chad and Egypt, with a capacity of $7.5x10^4$ km^3 of water (117). The Nubian Aquifer is storing prehistoric water, the water on which numerous Berbers tribes, all of the oasis and other settlements relay on for sustenance. Since the building of the Aswan High Dam there were noted disturbances as in referral to the aquifer recharge and to the overall seismic activity of the region. The

Aquifer itself had a large net recharge from the Lake Nasser. In the calibrated area of the Nubian Aquifer, that is in the vicinity of the Lake Nasser it has been estimated that it was recharged with $5.3x10^{10}$ m^3 of new waters in the period of the past 30 years, 1970-2000 (117). The areas of the Aquifer within 30 km of the lake were affected by the recharge during this 30 year observation period, and although observation ceased in 2000, the effect of recharging did not, while taking into account the rates of recharge it can be presumed that it continues.

This new recharge means that underwater levels are very high confirmed with observations of the surrounding wells and wadis, as the Palaeocene waters were recharged by new fresh waters from Lake Nasser. These higher water levels, together with the recent recharge and the aquifer itself are affecting the land salinity. Observed hydrostatically the depression which has a massive water body in the near vicinity at the higher altitude will eminently be prone to saline lands due to water capillary action; add to that the Saharan high temperatures with their high evaporation rates and an aquifer beneath it, very high salinity levels are evident. Egypt is no stranger to drainage problems and dealing with high salinity levels, since the building of the Aswan High Dam downstream lands had problems with pronounced salinity, both rain and irrigation, in the absence of leaching and proper drainage, can bring salts up to the surface by capillary action. This had led to yet another big state founded project. The one of mass drainage around the shores of the Nile River downstream of the dam, as the building of the dam rose the underwater levels downstream. *The total investment cost in eleven large scale agricultural drainage projects over the span of 29 years, from 1973 to 2002, was estimated to be around US$3.1 billion covering the cost of design, research, construction, maintenance and training Q.*

Political history

Advisors to the Egyptian Ministry of Water Resources and Irrigation, such as Mohamed Sultan and Baha Abdul Naga, warned against using this location, as through their findings, they concluded that the area would have major problems with land salinity due to rates of evaporation and the fact that the area is a limestone plateau. By employing the Groundwater Modelling System (GMS) developed by the US Defence Department, Mohamed Sultan was able to make a calibration model for the terrain with precision of 0.5 to 5 km (117). He used it to calculate the rise in underground water levels surrounding the lake Nasser and Toshka Wadi for 1970, 1980, 1990 and 2000, which correlated with the actual data from these years. This calibration model was than further used to predict later rises in underground water levels for the years 2020 and 2050. Similar to the years that passed, the new predictions are expected to fully correlated to actual data measured, hence giving us an accurate picture of lands prone to high salinity, under which the Toshka New Valley irrigated fields belong.

Construction and investment

The Toshka “New Valley” project was from its beginnings considered as the saviour of the nation, it was developed to protect the country from flooding, provide new arable land, approximately 5 952 500 ha (2.5 million feddans) in two phases (118), jobs, and act as a sanctuary for the growing population of Egypt. The New Valley Project was envisioned as a new migration destination which in the future would work in tandem with the overpopulated, urbanised Nile Valley to accommodate the rise in population expected in Egypt by 2050.

The project originally developed as an idea for the second Nile River Valley that would have help move the population out of the over populated valley of the Nile River in 1958

by President Gamal Abdel Nasser (17), when he envisioned it alongside construction of the Aswan High Dam, with hope that it would be able to expand Egypt's already shrinking amount of arable land. Soon after the start the project, it was abandoned. However in 1997 the nation's president, Hosni Mubarak, restarted the project (17) under the new name of "New Valley". The socio-political reasons for re-starting this project were numerous and broadly discussed in the Master thesis of Emmarie Kathleen Deputy which was entitled "Designed to Deceive: President Hosni Mubarak's Toshka Project" published by The University of Texas at Austin, in 2011, so they shall not be discussed here in detail. Although there are some valid points in the thesis, I would not agree with all of them, and would especially point out what was overlooked in the thesis which was that the opportunity was there.

The most important factor in President Mubarak's decision to restart the New Valley Project, in my opinion, is that an opportune time had arrived. The water needed to be diverted as it would have otherwise endangered the dam and since they had made the diversion canals and the Toshka lakes were formed, it would have been heedless to fail starting the irrigation project and just let those huge water bodies evaporate without using any of their potential. In this way even though not entirely successful, the people have profited from the irrigation project in different agricultural activities.

So nearly forty years after it was proposed by Gamal Abdel Nasser's government, construction of the Toshka canal begin under Hosni Mubarak's government in 1998. The project, which was written off by Nasser as a failure, was reinitiated by Mubarak in the 1990s as the beginning of "great promise" for the country's youth. Between 1998 and 2002, the Toshka canal was built promising to deliver excess water from Lake Nasser to the Toshka Wadi which comes to include lakes with approximately $5x10^9$ m^3/yr of water being used to reclaim $0.5x10^6$ acres of desert land (117).

At the centre of the Toshka project was the Mubarak Pumping Station, a masterpiece of modern engineering, which cost $436 million to build and which was completed in March 2005. It is located in the south-central part of the lake and is completely surrounded by water (119). It has 24 vertical pumps which are installed in two parallel lines along both sides of the station. At any one time, only 18 of the pumps are running, 3 are used for maintenance needs, and 3 are kept in reserve. The station, with an open 50 meter deep intake channel, the deepest inland channel of its kind, makes the complex able to pump 1.2 mill m3/h (119). The canal to which the water is being pumped is 30 meters wide, being dug out of rock and sand and coated with impermeable concrete to prevent seepage. The channel is called the Sheikh Zayed al Nahyan Canal named after Sheikh Zayed al Nahyan, President of the United Arab Emirates (UAE), who financed the project with 100 million US dollars (119). Still unknown to the author is why the Egyptian government opted for the canal and not for the pipeline as a solution for transporting the water through desert, as to the best of the author's knowledge, such construction would have been cheaper, easier to manoeuvre and more suitable in regards to the channel's desert evaporation rates.

Expectations

As explained above the Toshka project was seen as a form of national salvation for the rising population and was planned in two phases. The first one lasted from 1997-2007, was supposed to deliver 1 190 500 ha (550 000 feddans) of new agricultural land (118) and was supposed to divert 10 % of the water from the Lake Nasser together with the finished construction of the Mubarak Pumping Station. The second phase was proposed to last from 2007 until 2017 and was meant to reclaim 4 762 000 ha (2 million feddans)

overall making new jobs and lowering the unemployment rate while reducing food insecurity and providing housing for 20 % of country's population (118).

Delivery

Today the project consists of a pumping station, the Mubarak Pumping Station at Lake Nasser, a major canal known as the Sheikh Zayed Canal and four minor branch canals totalling 240 kilometres of canal and some 35 700 ha or 3 % of the first planned 1 190 500 ha of irrigated land. The second phase was entirely abandoned in 2005 and the completion of the whole project was extended to 2020 (118).

Lessons to be learned from the Toshka project

Although the Toshka project is not an afforestation project, it is a very important agricultural-irrigation project for Egypt, a project that was meant to conquer the desert with agriculture, and provide jobs and security through land reclamation. Not only that, but as Egypt's water minister when the Toshka project started and now head of the Arab Water Council in Cairo, Mr Mahmoud Abu Zeid puts it: "Not only as a new area for people to move to (referring to Toshka), but also being close to the borders with Sudan. I mean, we need to have a new community there, an Egyptian community to live there. And also, you never know what will happen between the two countries in the future. So it has a strategic aim, and also a development aim supported by decisions from top-down." (120). It is a project supported from top and bottom socio-political actors which had previously failed due to unsuitable engineering.

It is the project that inspired me to start my thesis as inadequate engineering was such an obvious problem below the surface of many more, and using pipelines instead seemed to be a very easy fix.

Figure 70. The sign announcing welcome to the New Toshka City

The Toshka project has a long and not so glorious history, but nevertheless a great one from which much can be learned.

Observing socio-political issues, the most important one is that there is the political willingness to participate and help settle people outside of the Nile Valley; one of the crucial aspects of Egypt welcoming the 21st century with growing population under control and safely distributed throughout the country. This multipurpose project was meant to relocate 20 % of Egypt's population, meaning approximately 17 million people to the New Toshka City. Even though still undeveloped the city was a promised land to Egyptian youth, and there is still willingness among the population to relocate and start their lives in the New Valley, which is a very important factor in such endeavours.

Technical issues arise from the use of the canals in the hyper arid deserts like the Sahara. No matter the impermeability of the material they are made of, concrete in this particular case, is completely unsuitable considering the evaporation levels present in the desert. This raises the salinity levels as the water that reaches the crops from such a channel in this vast arid place, is too thick from the evaporation that occurs during its journey. A journey of 126 km from Lake Nasser through the open channel to fields that need to be irrigated, which themselves are prone to salinity as covered previously, due to an underwater table rising.

Therefore, in this research we are building a case for using a sustainable pipeline system for transporting the water and fertile sediment mixture, in a biomimicry manner so that we overcome the initial setbacks that happen due to high evaporation rates and to be able to deliver water with the desired content, ameliorating rather than increasing soil salinity levels.

The Toshka project had difficulties from the very beginning, with the main problem being the high salinity of the land in the designated area of the project. Despite advice to the contrary, the Egyptian government chose to pursue this project location and go ahead with planned development, all the while knowing that the lands would be faced with high salinity and face very harsh conditions at the location where the project now stands.

The problems of the Toshka New Valley project are manifold. Ranked high amongst them is the poor decision making on the part of the Egyptian government of the time which led to this multi-million-dollar public funded project turning into a bottomless pit. Insufficient research had been undertaken to ensure that the implemented actions would lead to a productive future. One of the main indicators of this is that the land reclaimed is at a lower height than the lake itself, and stands above the aquifer, in one of the driest regions on the planet, leading to inevitably high levels of land salinity, while trying to have a conventional agricultural approach with common crops, in simple rotational patterns. My research has aimed to address the high salinity levels, with appropriate plants and applying appropriate afforestation methods suited and calculated for such hostile conditions. One of the more extravagant aspects of this project is the Mubarak Pumping Station. The mountains surrounding the lake are higher than the lake itself, so using the concrete canal required the construction of the largest pumping station in the world, so that it could pump the water upstream. This solution led to huge water losses due to the fact that the water is being pumped at a latitude of 23 degrees North through a 30m wide concrete canal, in the middle of one of the most arid deserts in the world. The little water that does reach its destination is firstly much thicker than is desirable. Secondly, it is without any nutrients as the pump is positioned in a way so that it does not get any silt from the bottom of the lake. But even if it did have the ability to gather silt, it would not have been able to deliver it through the concrete canal to the new irrigated land, which is made up of limestone and sand. This leads one to conclude that a lot of artificial fertilisers would need to be used to nurture those new lands if anything is to be grown there.

Furthermore, one of the more permanent problems is the temperature, which is regularly in excess of 50° Celsius (121) during the day and as low as 0°C during the night, and which, if not addressed properly and without fine-toothed planning, could put a permanent stop to any project at that location. Such high temperatures make water evaporate faster than the plants and soil are able to absorb it, literally wasting water and resulting in massive salt lakes rather than arable land. This phenomenon is now forcing local farmers to abandon fields and use new patches of land, not focusing on creating or growing soil organic content at all.

The question which looms largest when viewing the literature on the Toshka project and its many idiosyncrasies is why exactly certain decisions were made. For example, one has to wonder whether the use of a canal instead of a pipeline to transport such a massive amount of water was a well-informed, carefully calculated decision or one devoid of logic. As opposed to the Toshka project, my research targets non-saline lands and aims to connect oases in between themselves, with an aim to infuse a micro climate change and allow for a more natural way for green areas to develop.

There would not be any loss of water due to evaporation during the transport phase, as pipelines would be employed instead of a canal, which would prevent thickening of the fresh water that is meant to supply the crops, and be among other measures that will be employed to reverse high levels of land salinity. At the same time the pipeline would allow for unobstructed transport of fertile and rich sedimented silt, making more usable soil and enriching those presently available; growing soil each step of the way, by using pipeline transport and carefully selected plants at the same time.

Different approaches, methodologies and technologies available for implementing afforestation projects in semi-arid, arid and hyper arid regions

Under afforestation projects, as explained in the beginning of this chapter, can be considered anything that will have a certain number of trees which will grow a desirable canopy that falls under the regulations of the FAO and is also in co-ordinance with the regulations of the given country where the afforestation project is situated in, having been planted on land with more than 50 years under different use than forestry. If we take this research as an example we can have plantations of palm trees, mixed with Moringa genus and pulses, which would be considered an afforestation project. In this part I will try to explain all approaches, methodologies and available technologies that are in use in afforestation projects. I will try to explain fully why I have chosen specific methods and the ones I advocate to be used in Egypt afforestation project and across the Sahara.

In this part agriculture and afforestation will come very close together. This is because the afforestation is seen by many leading institutions as naught but an extension to good and sustainable agricultural practices of the 21st century in dry lands. First I will explain some of the old agricultural practices that have led to a 25 % of land degradation (122) across the world that should have been long abandoned such as “slash and burn,” which is often mixed with bio-sharing methods and monocropping, or conventional agricultural practices. Then there is an introduction, followed by discussion and conclusions on the more modern and novel methods present more and more often in the fields across the world, which will be closely observed in this afforestation research.

It is important to note the old and destructive ways of agriculture so that we are able to appreciate afforestation through agroforestry in an adequate manner.

Slash and burn method

The slash and burn method is associated with cutting down the rain forests and burning the remaining foliage, which clears the virgin forest for subsistence agriculture and makes new agricultural land fertile for a short amount of time, or for the time it is needed for rain to wash off all the nutrients from the soil. Slash and burn is a very old technique spread across the world, and may well be one of the oldest methods on the planet that people have been using for creating new agricultural land, for millenniums, not just today. During the Neolithic Revolution people developed agriculture and made more permanent settlements. When food supplies were diminished as hunting and gathering decreased, they found that they needed to free more land for pastures and crops than what was available to them.

This is one of the arguments as to why they started cutting down forests, shrublands and woodlands: to clear more area for new agricultural fields and new pastures. And the most effective way was to cut and burn the undesired foliage. The technique was spreading fast and soon the Mediterranean zone had lost all of its thick evergreen deciduous and pine forests, as documented in Greek literature. In Roman times wood had become so scarce that they started building houses out of stones as it was a more available material. The technique spread fast, devastating south and central Europe, with the alpine region excluded, as agriculture took its toll. In Europe there were forest areas that had survived this exhausting agricultural practice, but only the Nordic forests were spared this early deforestation and were not affected by this method until the late 17^{th} and 18^{th} centuries. This period of slash and burning across Europe matches the period of great migrations of the people in Europe, after the fall of Rome and until 800 AD. The method was spread across the world. For example, in North America it was used with the first settlers coming from Europe, but it was soon abandoned as the development of a generalised capitalism followed which made land ownership become important. It was a very well-known method used by all civilizations and farming people all over the world, but a method always tightly connected to subsistence agriculture, and abandoned when the need for such disappears, or with the development of land ownership societies.

Today this practice is mostly present in very poor areas of the world, predominantly in rain forests, where farmers are forced to implement it for their families" own survival. Fields farmers today acquire in this manner are productive for a very short time, sometimes as short as two seasons. The rain washes away the nutrients from the soil very quickly, one of the reasons being that today most slash and burn farmers mostly till the hill slopes, as the lower land is occupied or depleted already. The second most important issue involves the beneficial fungi and bacteria that live in the roots of the trees, which dies out soon after the trees were cut. This means there would be nothing left to hold on to the nutrients in the soil, and they would then be easily washed away by high levels of rain present in the areas of rain forest as the crops and weeds that grow do not have as deep and as branched root systems as the trees do.

This way of cultivating the land, might have been reasonable in former times when there were not so many people living on this planet and not so many poor farmers competing for free land and when population pressure was lesser than what we have today. This method requires farmers to constantly move. Every couple of years they need to change their fields as they deplete nutrients depleted, therefore requiring from them to clear out a new slot of virgin rain forest, leaving behind them devastated land. Because of this need to move further and further deeper into the forest or higher into the mountain, the land behind them stays barren due to the constant cutting of the rain forests and not giving them enough time to regenerate. This practice is also a cause of a lot of landslides in such regions as frequent rains just wash off the topsoil. It is not

uncommon for farmers to meet on top of the hill, both starting the cutting of the forest from the other side of the hill, leaving both sides forced to relocate to another hill and travel further away from their homes and cutting deeper into the forest.

These recurring processes are why scientists and activists from around the world are trying to produce a sustainable solution for these farmers and to find for them a better way of living, one that does not demand constant moving and destruction. This type of farming, which for example in Guatemala results in a 1.19 % a year rate of deforestation, is not a good and sustainable method for the preservation of the planet's resources in 21st century; the slash and burn method is out-dated and has to be abandoned and substituted with more efficient and sustainable method rapidly.

One of the solutions to slash and burn methods is the Slash and Char method. This practice addresses some of the environmental issues caused by the slash and burn method, in particular the fertility of the land and the need to relocate to new locations, as it involves charring, but still not all. By charring the remaining trees and plants instead of burning them, farmer makes bio char, a very fertile substance usually added to the soil mix to increase fertility. This practice is closely related to the Amazonian regenerating black soil, *Terra Preta,* one of the most riches soils on the planet. But this method does not protect the virgin forest from being cut down in the first place. On top of that using bio char as a soil amendment anywhere further then 50km from the location where the char is made, turns it into carbon positive rather than a carbon neutral or negative practice.

A better solution to *slash and burn* and *slash and char* has been developed by agroforestry. It is called alley-cropping and is especially present in central and South America. A distinct inga-alley-cropping method has developed as a form of sustainable 21st century agriculture. This method will be further discussed below.

Monocropping

With the development of capitalism in industrialised countries, the development of commodity based instead of subsistence-based agriculture rose. This meant leaving behind the slash and burn method and engaging in more productive ways of farming. The beginning of the 20th century saw a majority of farmers growing multi crop fields, meaning that on average a family farm would have five or more different crops growing on their fields mixed with livestock production. By the beginning of the 21st century there was an accelerating shift towards farms with one predominant crop field type (123).

Monocropping refers to a huge land mass populated with only one crop variety, either referring to just staple food sources like grains and legumes or to plantations of single tree species as they are all equally destructive to the planet if planted on the same land year after year. The consequences of enormous biodiversity loss are evident just in the definition of *mono* meaning single or one. The great shift from poly-/multiple-cropping to monocropping happened in the 1940s and 1950s in industrialized countries, as the smaller family-based farms were brought together and consolidated into larger industrially owned and operated farms or factory farms during the period of mass migration to the cities from the time of the Second World War. On the other side of the world, the rise of communism after the war also saw many people leaving the countryside in pursuit of a better future in a newly developed factory town. This made the communist leaders develop agricultural cooperatives in the remaining villages, which again consolidated previously small family owned farms into large cooperative farms. Cooperatives would be advised by state experts to grow a certain crop on all

their land, and were guaranteed the purchase of the crop by the state, making the remaining farmers feel secure and provided for by the state. These types of decisions made it easier for the governments on both sides of the world to control the population, (just a reminded on great Irish potato famine) to control the market, the production and to control the stock market prices, a great introduction to the Monocropping method of 20th century.

Monocropping, aside from being used as a great manipulation method highly dependent on fossil fuels, petrochemicals and industry, has affected the farmers far more generally than just politically. However, there is always a positive side and monocropping was that which enabled farmers to become more specialised in specific crop varieties and gain deeper knowledge about them, allowing them to invest in specialised usually very expensive machinery that is needed for more efficient sowing, harvesting and spraying their specific crop.

The three most commonly monocropped types of crops are soybeans, corn and wheat, all staple food sources together with many trees cultivated in plantations like palm oil trees or eucalyptus trees. Growing one plant type on the same piece of land year after year depletes the soil of its nutrients, as the plant takes the same nutrients it requires all the time, every year, until it has completely depleted the soil; which forces the farmer to artificially add those specific nutrients by using artificial fertilisers. In most cases the farmers are forced to add nitrogen, phosphorus and/or potassium-based fertilisers. All of these common fertilisers are either dug out of the earth, from deeper and deeper mines, and/or are derived from fossil fuels, natural gas most commonly. In those cases, the methods of their procurement and processing are bad for the planet's environment and enlarge the dependency on industry and fossil fuels. This affects soil health, which becomes acid and high in heavy metal content, making it poisonous for some species that live in it. Intense use of industrial artificial fertilisers derived from petrochemical industry also affects the soil food web and soil biodiversity. The environmental consequences do not stop there. These inorganic fertilisers from industrial farms are often washed away by rain which is then absorbed by streams and rivers which bring them to the lakes and oceans causing severe water pollution. The high phosphorus and nitrogen levels create algae blooms, which then deplete the water of oxygen causing the creation of dead zones in the oceans and lakes, severely affecting biodiversity and life on the planet, such as the Baltic Sea.

The other negative aspect of monocropping fields is that they make a great breeding ground for bacteria, fungi, insects and other pests, as the pests can rely on the food source, the monocrop, being there the next year round. These fields than become susceptible to fast and wide spread diseases, which could have otherwise been prevented by the use of crop rotation or some other organic farming method. Farmers are then forced to use industrial made pesticides, such as herbicides (weed killers), insecticides, fungicides and microbicides (bacteria killers) as necessary in intensive monocropping cycles. The use of these results in killing the targeted pests, but also in killing of the untargeted ones and beneficial ones, like bees, beneficial fungi and bacteria that enriches the soil quality and health leading to an eminent biodiversity loss. These practices lead to water and land pollution and also harm the farmers themselves as well as the end consumer, with various health effects, from different minor skin and breathing obstructions to cancer related ones and even mass suicides noted in tree Indian states with monocropping cotton farmers (124). This also adds to

the emission of greenhouse gasses from agriculture that now account for 24 % of global emissions by economic sector[8].

The crescendo of monocropping by many scientists and farmers is seen in the genetically engineered crops; crops designed in that way to be pesticide resistant and/or to have a pesticide producing gene imbedded into their gene codes; the agriculture of the 21st century. Monocropping, as if not bad enough on its own, in this way becomes an even more destructive practice, as the GE crops contaminates the surrounding non-GE crops and nature with adverse negative effects that are unaccountable. The harmful effects on key species like bees and beneficial insects, butterflies and/or beneficial soil life like fungi and bacteria, as well as on non-targeted species, possible human health concerns, all with consequences that are unknown to us, understudied and underexplored today. The whole subject of genetically modified organisms is highly debated in science, with industry and corporations profiting from patented DNA codes arguing and subsidising pro side of the argument, while some farmers and consumers are arguing for independent research studies, more secured labelling and labelling in general such as in countries like the USA that introduced GMO decades ago. This is just a tip of the iceberg. However, the USDA report from 2011 specifies that 94 % of soybeans, 90 % of cotton and 88 % of corn grown in the US are genetically modified, leaving the whole continent open to GE contamination (123).

Monocropping of GE or non-GE crops requires intense irrigation, which further leads to soil salinization, declined yields and overall soil degradation to desertification at the end. All over the world 25 % of soils are heavily degraded due to a wide variety of factors; amongst them soil salinization, which is present in 20 % of worlds irrigated lands (approximately the size of France), 62 million hectares (125) are useless and does not just destroy the land but also uses excess water resulting in water shortages and insecurities. Monocropping, double-cropping (commonly referred to convenient corn and soy cropping together, as the same machinery could be used for both), multi or generally any-type of heavy industrial cropping dependant on fossil fuels are ultimately unsustainable and have to be abandoned in order to have food and water security in 21st Century together with healthy soils capable of mitigating the climate change upon us.

The year 2015 was declared an international year of soils by the Food and Agriculture Organisation of United Nations, bringing attention to soil preservation and regeneration to mitigate and buffer the climate change consequences.

[8] https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data

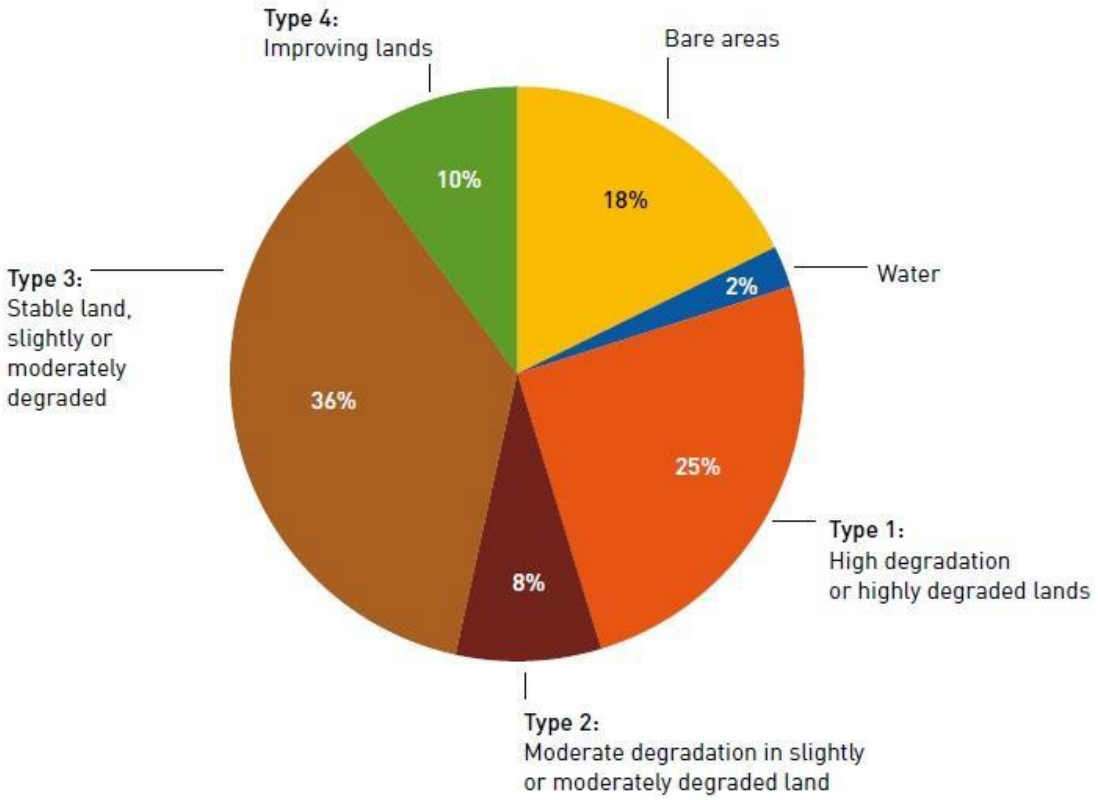

Figure 71. Current status and trends in global agricultural land degradation "The state of the World's Land and Water Resources for Food and Agriculture" (122)

Sustainable alternatives to conventional, industrial and inorganic agriculture
The term "industrial agriculture" refers to industrial monocrop production that relies on artificial and/or petrochemical fertilisers and pesticides; this does not refer to the actual ownership of the farm, as an organic farm can be owned by industry as well as by an individual farmer[9]. This work is based on the use of sustainable agricultural alternatives to industrial crop production for successful implementation of an afforestation agroforestry project in the Sahara Desert.

The main reason for choosing the sustainable agricultural approach does not lay in the common hype for organic produce, although usually demand makes the market, but in the clear scientific facts on the abilities of the living soil to store CO2, hence mend our planet climate faster and lower to no demand for fossil fuels within the organic approach itself, together with wholesome Earth preservation and soil building, which is the focus of this research.

Conservation agriculture, including no-till agricultural methods; organic fertiliser; sustainable agriculture and soil building with innovative pest management approaches; and water-management practices together with multi-cropping, intercropping, companion planting, beneficial weeds, alley cropping, crop rotation are all strategies being utilised in the Permaculture approach as alternatives to industrial crop-growing

[9] There have been some studies suggesting that an organic farm could have just as destructive practices as conventional farms, especially if the organic farmer does not incorporate all the approaches of organic farming but simply follows the fertiliser and pesticide rules leading to eutrophication, although this is very rare.

methods. The aim of this thesis is to present a possibility for a beyond sustainable agriculture practice in Egypt. In the previous chapter we saw that successful practices of afforestation across the world were predominantly relying on restorative agro-ecology and agro-forestry systems and on working with nature using the biomimicry approach or on high-tech solutions for utilising the desert for food production. Therefore, in order to provide Egypt with not just a sustainable solution but a "beyond sustainable" solution for the population that will be 4 times bigger in 2050 than it was in 1950, we have to rely on nature and work with it to firstly develop the conditions to grow the soil and then to maintain it with all the crops and greens, alongside while mitigating the predicted climate change to our advantage.

To choose the right approach we must first have a glimpse of all of them. The development of organic agriculture and all its different approaches, amongst them *Do nothing farming*, or *Natural farming* and *Permaculture,* started in the 1940s as a response to developing industry and farmers" dependency on synthetic fertilisers and pesticides, the new modern inorganic agriculture. However, before this time, at the end of 19th and in early 20th century the development of predecessors of organic agriculture started simultaneously both in Europe and in India.

A short history of organic farming

The British botanist Sir Albert Howard, the father of organic agriculture together with his wife Gabrielle L.C. Matthaei, a British plant physiologist, who worked with him on numerous traditional Indian farms, were amongst the first to note the superiority of traditional Indian farming in comparison to conventional agricultural practices. Their research and development of these traditional practices were thoroughly documented in the book he published, "An Agricultural Testament," in 1940 which is noted as the first book and the first scientific book on organic agriculture, as the bible of organic farming, which kept getting upgrading later on.

Even before the work of Sir Albert Howard, in Europe a famous Austrian philosopher, social reformer, architect, and esotericist, Rudolf Joseph Lorenz Steiner (1861-1925) alongside many of his contemporise started to see the negative effects of conventional agriculture; being a founder of the anthroposophy movement he observed agriculture from a different perspective. Rudolf Steiner's approach to agriculture was more holistic than any of his contemporaries and it is still perceived as such. In November of 1924 his booklet of eight lectures on organic farming was published in response to farmers demand, as they had noticed the degrading of their soil in the recent years. To test his hypothesis and lectures Steiner formed a research group, the "Agricultural Experimental Circle of Anthroposophical Farmers and Gardeners of the General Anthroposophical Society" and established a farm. This later led to the forming of the biodynamic agricultural, the first comprehensive system of what was later to become the predecessor to the organic farming as we know it today. The same year Steiner formed the first certification and labelling system for organic production, the biodynamic certification, Demeter, which still exists and is active across the world including Egypt. Although biodynamic has been criticized in the past and referred to as a pseudoscience by some researchers, it had provided the world with the first systematic approach to an agriculture labelling system and first organic agriculture system as well.

In another part of the world, North America, an agronomist Franklin Hiram King (1848-1911) today seen by some researchers as the father of modern day soil physics, started his journey through Asia. Visiting China, Korea and Japan his primal focus was on their farms, which we would now call sustainable and permanent farms. This voyage made an impression on F.H. King and he started to write a book about it which was published in

1911; being described by Lord Northbourne, the founder of organic agriculture and also a man who coined the phrase organic farming, as a "classic" which "no student of farming or social science can afford to ignore." In this book he describes the now know methods of sister planting, inter cropping and human manure and many other methods implemented today in organic agriculture, and especially in Permaculture.

One of the founding fathers (mothers) of the organic agriculture, Lady Eve Balfour (1898–1990) published a book in 1943 called "The Living Soil" (126), based on her experimental studies from the 1939 Haughley Experiment. The book further led to the formation of one of the most prominent organic advocacy groups the Soil Association (127). The Haughley experiment allowed for many observations to be made for the first time and led to many conclusions in regards to conventional and organic farming methods, out of which three stand out on mineral levels, animal longevity and yield increase. Observed mineral level fluctuations measured in the soil which corresponded the plant life cycle and the different mineral levels present in the plants, with organically grown plants having the higher mineral content; second organically fed animals required 12-15 % less food input and were healthier and lived longer compared to their conventional counterparts, and the third important attribute were increased yields of organic plots.

Masanobu Fukuoka (1913-2008), grew up as a rice farmer who became a microbiologist working in soil science specialising in plant pathology in Japan. Early in his professional career he began to question the modern agricultural and everything he had learned by the age of 24. He quit his job as a research scientist and returned to his family farm in 1938, to devote the next 60 years of his life to developing a radical no-till, organic method for growing grain and other crops, now known as natural farming, nature farming, "do–nothing" farming or Fukuoka farming with many of his practices being incorporated into Permacultural approaches. His philosophy lies in observing the nature, as he first started excluding all the excess practices which finally lead him to the do-nothing principle, "as there is no greater engineer than nature and the best any human can do is mimic it" M. Fukuoka.

His favourite quote was: "Understanding of nature lies beyond humane intelligence."

Why temper with something that we cannot even comprehend? He saw everything in modern agricultural practice as an effect caused by something a man had previously done, example the infestation of pest-insects that required overuse of insecticides, he observed as produce of eliminating their natural foods -weeds, elimination of weeds with herbicides, caused decreased levels in soil nutrients which further required fertilising with artificial fertilisers, which further on deepened the humane dependency on fossil fuels while also poisoning our waters and so on… He decided to try to stop the magic circle and just simply observe what happens when one by one each of the modern agricultural practices are excluded from the cycle.

His meticulous observation and of course his scientifically trained mind had led him after years of practice to these five basic principles of do-nothing farming:

1) No cultivation – no ploughing, no tilling, zero tillage or direct drilling
2) No chemical fertilising or preparing compost
3) No weeding by tillage or herbicides
4) No dependency on chemicals
5) Pruning of trees is unnecessary

He used plants with deep roots to pool the nutrients and loosen up the soil like daikon, radishes and dandelion, while he used white clover to fix the nitrogen in the soil. He

also planted a wide variety of medicinal herbs and weeds as ground cover like mustard, buckwheat ad shitake mushrooms. Planting nitrogen fixing trees like Acacia trees alongside his citrus and mango trees gave the soil an additional deep boost of nutrients and made his hill have the structure of a natural forest with canopy and lower trees, shrubs, climbers and ground cover.

He was criticised for his strict approach to do-noting farming, and for it being difficult to implement, especially in transitioning periods, from conventional to do-nothing farming, as the yields loss are greater than the 10 % originally foreseen by Fukuoka. Nevertheless Masanobu Fukuoka was widely acknowledged as an expert in organic farming, for which he had received multiple awards such as the Desikottam Award, India's most prestigious award, the Philippines" Ramon Magsaysay Award for Public Service, recognised by the equivalent in Asia of the Nobel prize and in 1997 he received the Earth Council Award from the Earth Summit+5 forum in Rio de Janeiro, presented to him in person, at a ceremony in honouring him for his contributions to sustainable development (128).

After the second world war the world inherited an abundance of chemicals made for states of war such as the infamous DDT and Ammonium nitrate (NH4)(NO3). With their employment in conventional agriculture as pesticide and fertiliser the *Green* Revolution began.

In the years that followed more and more scientist turned towards chemicals out of fear from food depletion and population overgrowth which big businesses used to their advantage and so the ear of soil degradation, depletion and destruction begun.

Rachel Louise Carson (1907 –1964) scientist and naturalist, the writer of the *Silent Spring* published in 1962, worldwide best seller, which most likely led to the US government's ban on DDT a decade later, was often credited for the lunch of the world environmental movement. Years that came after this publication saw the publication and formation of many now important governing bodies such as the International Federation of Organic Agriculture Movements (IFOAM) 1972, formation of Permaculture, during this decade Rodale Press published a series of how-to books on organic farming encouraging Americans to try this approach themselves and Fukuoka's great book *The One-Straw Revolution* was published, too.

The next decades welcomed stronger pressure from consumers towards government's which led to the continuous improvement of organic regulations and norms on state, country and continental levels.[10]

The 21st century

[10] One of the very interesting approaches in organic agriculture that had developed relatively late in comparison to others is Organopónicos, an organic urban agricultural approach that had developed in Cuba in response to the fall of Soviet Union 1991, characterised by small concrete garden beds parallel to the use of all the other "conventional" organic methods.

Today the 21st century has seen a great increase in consumer interest towards organic produce, making more space for new research and development to be implemented in this section, regardless of the still predominant industry driven by conventional agriculture, which with agribusiness makes this imbalance highly visible through research funding and government lobbying that still has a central effect on agriculture-related science and policy, which continues to develop in non-environmental directions such as deepening the dependency on petrochemicals, chemicals and biotechnologies, like genetic engineering etc.

Today many of the leading sustainable agricultural organisations put a clear distinction between themselves and genetically engineered crops. However, as a lot of money has been invested in the field of genetic engineering, there has been an abundant amount of newly published scholarly articles coming from respected scientific journals, making links to sustainable agriculture and genetic engineering. If this trend continues, with the support of multinational corporations that are in possession of gene patents and seeds, the question arises, how long will the sustainable agriculture associations be able to defend themselves from being pushed into genetic engineering production, or being diluted with such science? Or will they be able to protect the name from being mixed with genetic engineering? And will they still be willing to?

This will see new niches between sustainable agriculture being formed, no doubt, (already present in sustainable development as two paradigms “strong” and “weak” approach), most likely some in support of genetic engineering, some highly appose to it and some neutral ones that would see economy as the strongest link in the sustainable trinity. In order for this research to be readable in future generations, one of the most important distinctions to be made is one between sustainable and organic agriculture. To make a clear difference between sustainable and organic (under which Permacultural resides) agriculture approaches is that the sustainable approach does not yet strictly exclude genetically modified organisms, while the word *sustainable* is not owned or protected properly from misuse by the multinational producers of the genetically engineered organisms. Therefore, even today we can find articles containing the words sustainable agriculture that actually promote the use of genetic engineering as one of the four main pillars in sustainably fixing the nitrogen in the soil, while the organic agricultural approach strictly opposes any use of this type of biotechnology.

Organic agricultural methods are internationally regulated and legally enforced by many nations, based in large part on the standards set by the International Federation of Organic Agriculture Movements (IFOAM), while sustainable agriculture does not have such a strong influencing body. Although many organisations appear through different search engines, none has set out standards to be followed across countries except the base trinity pillars set by sustainability norms as economic, environmental and social wellbeing of farmers and farm. The only organisations that appears to lead in this field, but is not solely related to sustainable agriculture, is FAO, the Food and Agriculture Organisation of United Nations, which on the other hand does not oppose genetically modified organisms except in one article published in 2003 (129).

Most important characteristics of nowadays sustainable agriculture are aligned with organic agricultural, as they promote information intensive instead of energy intensive labour and cyclical oppose to linear conventional agricultural input approach. Both sustainable and organic approaches see the farm as an ecosystem rather than a farm-factory, both trying to integrate the eEnterprise into the farm not to separate it, while building the farm diversity in plants and animals unlike the monoculture of conventional farming. With the development of local farmers markets, strong internet support both approaches are trying to encourage high value produce and added value to the farm

(exp. jams made on the farm) as oppose to conventional agriculture, promoting active marketing and *know your farmer* methods. Both argue for multipurpose equipment as oppose to highly expensive single use equipment present in conventional agriculture. Both argue for conservation agriculture and one of the main differences is the stand on genetically modified organisms.

All the other approaches that will be further analysed can be put under organic approach, some had developed earlier some parallel but all have the strict ban on genetically modified organisms clear. This is why the approach this thesis develops goes beyond sustainability in many ways, out of which the production of new soil, the land that was not previously available to current generations and the decision not to use genetically modified organisms are the key ones.

The available conservation approaches to agriculture

1) Biodynamic farming

Biodynamic farming developed by Rudolf Steiner in the 1920's is the first documented system approach to organic farming. Even though at that time there were many organic farms present in the world, that were or were not aware of being such and were or were not shifting towards conventional agriculture, Biodynamic farming is the first system of organic farming that has been developed with a scientific and systematic approach towards agriculture rather than the classical path of trial and error which developed in different regions throughout the centuries.

The approach itself has received a lot of criticism from the mainstream scientists, predominantly concerning its way of approaching the farm as a holistic system.

The main characteristic of the Biodynamic approach is observed in other conservational approaches, values they have in common, are to restore, maintain and enhance the ecological harmony of the farm. The way by which it is different to other practices and what makes the Biodynamic principle unique is that it observes the soil, plants, and animals as a single system, linking them in a one single holistic element belonging to the Earth as a whole. But this system not only reaches within the planet, it goes further, beyond relying on astrology for sowing, planting, and integrating astrology into agricultural practice on multiple occasions. This last part would be the one that many modern day scientists have a hard time connecting to, linking the Earth and the universe (as if the Earth is not part of the universe) and the possibility of effects of the moon, planets and stars on a good harvest. However, lots of the Demeter certified wines have won the highest prizes in the world of classy wines. Many studies, especially in California, tried to explain the relation between the quality of the wine and the biodynamic agriculture, yet none have succeeded in it, giving the closest explanation that the basic organic wines would have tasted the same as biodynamic ones, and others have shared that the mere meticulousness and knowledgeableness of the biodynamic wine makers is what makes the difference in the first place.

There are nine principles that were published by Steiner for increasing the soil fertility and all of them require in the best case very peculiar preparations. All of the nine instructions require some mix of plant and dead animal parts to be placed underground in special places, for a certain amount of time in a more or less ritualistic manner, accentuating the spiritual, mystical and astrological part by which this approach is known. Another interesting aspect of Biodynamic farming guidelines is that it requires 10 % of the farm to be left aside for biodiversity purposes. This land, depending of the natural surroundings, can be developed as a forest, wetlands or similar natural structures, which are very good practices that help the local habitat and should be

further investigated. Demeter previously mentioned as developing the first certification and labelling system for organic production, the biodynamic certification, is still alive today and is active across the world including Egypt, where Biodynamic farmers have achieved notable results.

This Biodynamic approach has one important feature and that is helping nurture the local habitat with its 10 % rule. It may not be as important for this research, but it is important that different researchers do not dismiss this approach immediately based on its closeness to pseudoscience, before a more thorough research.

Improving humanity through its surroundings and foods that we eat is also one of the important narratives here, like it is in the next approach.

2) Do-nothing farming, Natural farming, Nature farming

Do-nothing farming is in many aspects close to Biodynamic approach, this is the most evident in its holistic methodology and approaching nature as a perfect whole. Fukuoka goes further and deeper in his teachings than Steiner had an opportunity to, he develops a philosophy, a one more deprived of ego that is much present in the Western way of thinking and more reliant on the Easter philosophy of Buddhism and Taoism. On the other hand even though the Do-nothing method shares many core values with many other organic methods do, as you will see, their core values in preserving the humane health and wellbeing together with soil nourishment and biodiversity is approached from different perspectives.

From Fukuoka's perspective humanity is a part of the whole, one part of the greater puzzle, while many western approaches are similar or derived from his approach, still see the nature to be there for the use of humanity, this perspective had greatly influenced his work and his teachings in developing his method. The approach developed through his 60 years of observations, meticulous work and practice.

Aside from its five main principals, Fukuoka developed the sowing of seeds with the help of seed balls. This specific technic had developed from a need to protect the seeds in a natural way against drought and seed predators like bugs and birds, and it is believed to have been used since ancient times in Mesopotamia and Ancient Egypt. In his book *Sowing Seeds in the Desert: Natural Farming, Global Restoration and Ultimate Food Security* which he based on his experiments in Somalia, Ethiopia, Greece, United States and many other areas affected by desertification, he finely describes the way of the *nendo dango*, "earth balls" in Japanese, can be successfully employed to fight the desertification proceeding in most arid regions. There he proposes sowing in great amounts, as he had travelled to east Africa in the mid 80's, burdened when witnessing western culture's destruction of food and farmers" security by agribusinesses monoculture plantations of coffee, tea, cotton, peanuts and sugar. He became more than ever certain in his own philosophy that until the man doe starts desert greening there will not be true food security. Proposing that US and European countries instead of sending bread, which indigenous people do not eat and canned foods, should start sending them seeds of diverse vegetables, herbs and crop which could be made into seed balls and sown in deserts providing proper nutrient rich source of food and direct income for local farmers, ultimately greening the desert and securing the global food security. He propagated animal husbandry and use of planned and smart humane labour instead of heavy duty expensive machinery. Do-nothing farming introduced the need for short, medium and long life span plants introducing in certain ways a form of poly-culture, where companion planting is much accentuated.

Sowing seed balls made from clay, compost, worm castings and some fibre, like finely shredded paper, cotton or wool for stronger structure made by hand or in concrete mixers, gives the seed proper protection not only in the desert conditions but anywhere. This method especially applied in guerrilla gardening, is a fine and tested approach of sowing in deserts. The clay as in many afforestations connected to warm deserts will play its role of providing the moisture after the initial irrigation, allowing for a more sporadic irrigations in the future, compost and worm castings will provide the needed nutrients and fibre gives it a structure so it is not as fragile to handle, prevents early openings of a seed ball and it gives prolonged nutrients to plant further on development. With this kind of equipment, the seed does not have any other option but to flourish.

Do-nothing farming served as a starting point for many now recognised organic approaches, as it is developed to be a base line, to only give guidance that has to be adapted to local conditions and always under one main principle respect nature and be a part of it.

One of the notable followers of Fukuoka's principles was an Indian farmer Bhaskar Save (1922-2015), in Gujarat region, who had after trying out conventional agriculture in the 50s shifted entirely to natural farming and alongside present desertification in his region managed to create the heaven on Earth, the best example of harmony and an even better farm by Fukuoka's standards than Fukuoka's own farm, in Fukuoka's own words. Save played a great role in the recognition of India's farmer suicides due to conventional agriculture. He received the "One World Award for Lifetime Achievement" by the International Federation of Organic Agriculture Movements in 2010. His farm is partly a forest garden.

3) Agroforestry - Food forest - Forest garden – Forest farming

There are numerous names that throughout countries and continents had describe the use of forests mixed with crops producing trees, crops and/or animals, this is to be expected as this way of utilising resources is one of the oldest ways humans had used agriculture. Among them there are some notable differences, however to mention and explain all of the recognised approaches in this thesis would be impossible, therefore I will be focusing on some of the most influential approaches include Forest gardening, Food forest, Forest farming, Inga alley-cropping, alley-cropping, agroforestry and Silvopasture.

Maybe the easiest way to classify them would be from the virgin forest to plantations. Virgin forests or old growth or primavera forests are the pure nature, untouched forests, maintained and managed only by nature, forest that distinguish themselves with the presence of rotting wood in the soil; then there are partly managed forests for timber or crops which would see planned cutting down of trees; the third are allay cropping types of different levels of humane interference, sometimes with more or less full areas of untouched virgin forest, or in case of Inga alley cropping an alternative for slash and burn, a highly destructive method of agriculture. Then there are planted new growth forests, which could be diverse reforestation projects with projected human benefit or timber or/ and crop producing and the last one would be plantations, usually consisting of only one type of trees, monocrop plantations.

After this age classification the level of management and attention classification from *the Forest faming* comes up as it seeks to explain the benefits from the forest from non-timber forest products. Here we can observe four types of forests, starting from least intensive to most intensive, Wild-crafting roaming the forest for mushrooms and wild-

edibles, without any humane involvement in nurturing the produce, Forest tending includes planned cutting of trees to help the growth of desired species, but no planting is present, Wild-simulated tries to maintain a natural environment, while enriching the local non-timber forest products distribution in the forest to achieve a greater renewable supply of the products, its characterised by minimal disturbance and natural growing conditions, that ensure that products will be similar in taste, appearance and quality to those harvested from the wild-crafting, and the most intensive way the Forest gardening, which represents the imitation of the forest thought heavy input of labour (for such agriculture) in an attempt to mimic the natural forest with crop producing trees while utilising all seven layers represented in the natural forest.

Out of all the mentioned practices so far Agroforestry is the most recognised. Many scholars defined as a sustainable way of agriculture in the 21st century; Agroforestry is mainly described with four "I" approach: intentional, intensive, integrated and interactive management.

The University of Missouri Center for Agroforestry defines it as (130):

"Agroforestry is new market opportunities. Sustainable "climate-smart" agriculture. Land stewardship. Habitat for wildlife. Improved air and water quality. Diversified farm income. Increased wealth for rural communities."

There are many recognised uses for agroforestry, among them afforestation, parks, shade systems, alley cropping, fauna-based systems, boundary systems, physical support systems, agroforests or better known as Forest gardens, edible-forests, forest farming, etc.

In 1930 in Japan Toyohiko Kagawa a Japanese's pacifist highly influenced by J. Russell Smith's book *"Tree Crops – A Permanent Agriculture"* started his own movement in forest farming by advising farmers located up the hill to plant nut trees, feed the pigs the nuts, sell the pigs gaining short and long term income and also preventing nutrient loss and erosion. Nearly half a century later in Europe Robert Hart started his own movement inspired by Toyohiko Kagawa, a food garden in moderate climates. Maybe the most valuable observation to be acquired from Robert Hart's approach is the seven layer classification system later adopted by the Bill Mollison and David Homeland in the Permaculture. Robert Hart's seven layers of forest consist of:

1. "Canopy layer" consisting of the original mature fruit trees
2. "Low-tree layer" of smaller nut and fruit trees
3. "Shrub layer" of fruit bushes like berries
4. "Herbaceous layer" of perennial vegetables and herbs
5. "Underground" dimension of plants grown for their roots and tubers
6. "Ground cover layer" of edible plants that spread horizontally
7. "Vertical layer" of vines and climbers

Very distinguishable are silvoarable systems such as alley cropping systems who are used in tropics to provide shade for crops and higher yields or like Inga alley cropping to prevent the locals to slash and burn the virgin forest in search for new arable land, but to provide an easy and effective way of increasing the soil quality and better yields as Inga trees (subfamily Mimosoideae) are nitrogen fixers. Silvopastures are another layer of integrating forest and trees management into successful agricultural practice as they apply managed grazing and tree production in essence. The other terms that appear thought literature especially in Permaculture books are *Food-Forest* or *Edible-Forest-Garden*, there is also a less know term used by a founder of Plants for the future organisation, Ken Fern *woodland gardening* but genuinely all these approaches

represent the view that the trees enable better soil protection from erosion, washing off of nutrients especially in tropic and to stop nutrient depletion.

The agroforestry approach is considered a key element in afforestation of the Sahara Desert, as it will give the economic benefit to the farmers, enhance the soil preservation from sand storms as well as soil built from increased organic matter and soil enrichment thanks to the deep root systems of the trees, this approach will prevent soil salinization and will eventually with proper maintaining allow for an effective carbon storage and climate mitigation method, giving farmers one more economical benefit of a possibility to go into carbon trading businesses.

4) Agroecology - Eco-agriculture – Ecoscaping

Agroecology on the other hand will provide to this thesis a valid benchmarking system that is built on the multidisciplinary lens present here. What is Agroecology one may ask? First to define the word, agro- coming from agriculture and ecology, or the in-house system study, a multidisciplinary field of biology, geography and Earth science, by stating this one can easily observed, that the Agroecology is a multidisciplinary science, that observes the agricultural ecosystems relaying on different fields of science to do so. There are a few definitions of this science and it all depends form the angle from which the observer views ecology, and then later Agroecology. In simple terms Agroecology is a science which observes the behaviour of plants, animals and humans within an ecosystem and depending on the ecological approach accepted within the Agroecology; we have Agro-population ecology and Inclusive Agroecology (131). By meticulous observations Agroecology provides a scientific foundation to understanding and developing a framework that uses the gathered knowledge from different fields and approaches such as agrology, agriculture, socio-economics, organic agriculture, Permaculture and other fields; all in a goal to comprehend the best approach for the farm or the location in question. It gives a unique view on the subject of sustainability, organic production and conventional agriculture, seeing and accepting that each farm, or ecosystem is different and requires a special approach, which through its benchmarking system it does provide. As defined by Berkeley University:

“Agroecology is a scientific discipline that uses ecological theory to study, design, manage and evaluate agricultural systems that are productive but also resource conserving. Agroecological research considers interactions of all important biophysical, technical and socioeconomic components of farming systems and regards these systems as the fundamental units of study, where mineral cycles, energy transformations, biological processes and socioeconomic relationships are analysed as a whole in an interdisciplinary fashion.” (132)

What goes into the systems observations by the FAO definition (133): A farmer’s system can be defined by:

1. Boundaries: What belongs to the farm/location, what is the environment in which it operates?
2. Components: Crops or cropping systems, livestock system, trees, buildings etc.
3. Interactions: The relationships between the components.
4. Inputs: Materials, information and energy originating outside the system but utilised within.
5. Internal Resources: Materials, information and energy originating within the system.
6. Products and By-Products

Thuds agroecology is not associated with any particular way of farming may it be conventional, organic, or otherwise as it is a study of variety of agricultural ecosystems and their in-between relations, but it is ruled by the principles of conservation agriculture and provides maybe the strongest scientific approach to conservation agriculture of all the approaches that will be named here. To achieve this agroecologists study questions related to the four system properties of agroecosystems: productivity, stability, sustainability and equitability, agroecologists study these four properties through an interdisciplinary lens, using natural sciences to understand elements of agroecosystems such as soil properties and plant-insect interactions, as well as using social sciences to understand the effects of farming practices on rural communities, economic constraints to developing new production methods, or cultural factors determining farming practices.

To successfully implement agroecological technologies into practice, such as technological innovations, agriculture policy changes, socio-economic changes, but mostly a deeper understanding of the complex long-term interactions among resources, people and their environment aside from detailed analysis of the system, we have to perceive the agricultural system as an ecological system as well as a human dominated socio-economic system, as here both go hand-in-hand.

Agroecology provides a framework by applying ecological theory to the management of agroecosystems according to specific resource and socio-economic realities, and by providing a methodology to make the required interdisciplinary connections. This is why such new interdisciplinary framework to integrate the biophysical sciences, ecology and other social sciences is indispensable for greening the deserts.

“Eco-agriculture” was coined by Charles Walters, editor and founder of Acres Magazine in 1970 to describe his own belief which became the motto of the magazine: “To be economical agriculture must be ecological.”

Agroecology and Eco-agriculture have in common the conservationist approach to agriculture, however the Eco-agriculture uses landscape a group of ecosystems as a measurement for its” whole, while the Agroecology uses ecosystem as a measurement of its systematic approach. They both have in comment that they observe the system a whole system, as do most conservational approaches do, but its” their systems that differ. That is how the measurement unit for Eco–agriculture can be as big as a few thousand km2 in vast Sahara or a just 10 km2 in Western Europe. Eco-agriculture observes the landscape as a measurement if unit as different features within it can benefit and contribute to socio-economical welfare of the people living there as well as it can harm it.

With the simple example, of a nice waterfall located up into the higher planes of landscape, a stream that flows thought a small virgin forest on the hill slopes and a few farms located in the valley. If the eco-agricultural approach is applied then the people would benefit from preserving the wild forest and waterfall, directly by engaging in eco-tourism, as well as would wild animals because there are no boundaries in this landscape but the natural ones, which enable undisturbed traffic for the wild life. This approach reconciles the conservationist approach to saving the wild life and biodiversity and the agriculturalist or economist who wants to produce more agricultural land, hence make more profit. This approach takes both in and makes them see benefits in working together with a strong accent towards protecting biodiversity and biosphere in general.

And while agroecologists see the farmer as a steward of the land, Eco-agriculturist sees the farmer as a partner of the land, someone who develops together with the land who is as much dependant on it as the land itself is dependent on the farmer a mutually beneficial relationship.

The practices applied in eco-agricultural approach to farming the landscape as the farmers need to come to an agreement, cooperative, commune or similar, are that farmers need to plane and manage protected areas, forests, wetlands, etc., together in their landscapes. Joined farmers need to link agriculture free areas, forest fragments, and wetlands within agricultural landscapes to enable the development of habitat networks and corridors that will support and expand the diversity of wild species. They need to reduce and/or reverse conversion of natural areas to agricultural areas by improving the productivity of currently utilised agricultural areas. This can be achieved by adapting the farming approach to mimic natural vegetation and ecological processes, realign on the integration of trees, shrubs, and grasses into agricultural production systems, and many already accepted conservational approaches such as organic farming, Permaculture, conservation tillage or no-till, improved fallow systems, on-farm crop or fertiliser trees, inter-cropping, and livestock diversification. This approach propagates better management of agricultural waste to protect the surrounding ecosystem by encouraging shifts from input-intensive to “knowledge-intensive” agricultural practices, as do all of the conservation agricultural apaches do.

The main point to take away from this approach is defiantly its lens as it observes the system in terms of landscapes, and I do believe this to be a good approach especially when developing an entirely new landscape of one country.

As for the Ecoscaping, it integrates the disciplines of landscape architecture and spatial planning with environmental science and provides an innovative approach in creating a sustainable and nature-friendly design and/or construction for urban environments. Ecoscaping prides itself on taking a holistic approach to sustainable land use management. This is not a conservation agriculture approach this is a landscaping architectural approach to designing a more sustainable and environmentally friendly urban environment while incorporating the existing situation into it. However, it does promote biodiversity and wildlife habitat preservation, which becomes of even greater importance with the ever growing urban sprawl.

To conclude this Agro-ecology is the science that studies the interactions between plants, animals, humans and the environment within agricultural systems, may the system be a single farm or a more complex one it first observes the boundaries, the inputs and outputs and then starts the dislodgement. The Eco-agriculture is an agricultural approach that observes the landscape as a single unit of agricultural ecosystem that reconciles the conservations and agriculturalist approach to biodiversity and farming, while the Ecoscaping is an architectural approach to diversifying and enhancing the life of people in urban areas and has nothing to do with farming.

5) Polyculture

Polyculture is one of the main conservational agricultural practices, sometimes considered an approach, but mainly representing one of the most important characteristic of the majority of the conservational agricultural approaches. Polyculture refers to using diverse types of crops in the same space, in an attempt to replicate and/or imitate the biodiversity of natural ecosystems, while avoiding large areas of single crops, or monocultures. It includes multi-cropping, intercropping, companion planting, beneficial weeds, and alley cropping. It is the raising at the same time and

place of more than one species of plants and/or animals; if animals are included than this refers to animal-husbandry. Polyculture is one of the principles of regenerative agriculture and Permaculture.

Polyculture greatly reduces susceptibility to disease as the spreading of one particular disease which attacks certain crop is inhabited by all the other plants that grow in the space between the two plants of the same crop, therefore by just growing different crop varieties or plants, this inhibits the spread of disease. For example, a two-year study in China showed that planting several varieties of rice in the same field increased yields by 89 %, largely because of blast which was decreased 94 % in comparison to monocultures, which made fungicides redundant (134).

Polyculture increases local biodiversity, can provide a biological pest control programme and is an example of reconciliation approaches to ecology while accommodating diversity within human landscapes.

6) Permaculture

In 1978 the phrase "Permaculture" was coined by two Australians, David Holmgren, a graduate student and his professor, Bill Mollison, to describe certain systematic methods of permanent agriculture. They were inspired and greatly influenced in their thinking by a truly sustainable way of farming by Fukuoka's Do-nothing farming approach.

In his book *Introduction to Permaculture,* Mollison said: "Permaculture is a philosophy of working with, rather than against nature; of protracted and thoughtful observation rather than protracted and thoughtless labour; and of looking at plants and animals in all their functions, rather than treating any area as a single product system."

Many of today's organic agricultural approaches can be classified under the Permaculture approach, however the Permacultural approach itself developed following J. Russell Smith's book *Tree Crops – A Permanent Agriculture*, published in 1929, Fukuoka's Do-nothing farming method, Percival Alfred Yeoman's (1904 - 1984) Keyline system, and Toyohiko Kagawa's forest farming in Japan in the 1930s, and Robert Hart's *Seven Layer Forest System* among others. The approach collected the myriad of high quality approaches under one umbrella, though different from each in its development and perspective (exp. Fukuoka's approach is against landscape intervention, while Permaculture and the approaches that later developed from it or parallel to it like Sepp Holzer's Hügelkultur advocate landscape intervention or are based on it). The saying that the whole is greater than the sum of its parts defiantly goes for Permaculture.

The three key characteristics of Permaculture that could be related to the three pillars of sustainability are defined as, first, care for the earth, which provides the conditions for all life systems to continue life and multiply. This first principle goes along with all the other organic and sustainable approaches, as care for environment and biodiversity are principles of most of them. The second principle is of caring for the people, or the sustainability social pillar, as providing access for people to resources necessary for their existence and social wellbeing. Return of surplus (the economy of it all, close but not the capitalistic third pillar of sustainability) or the third principle, is reinvesting surpluses back into the Permaculture system to provide for the first two. This includes returning waste back into the system to recycle into usefulness, striving towards a no-waste system. Therefore, the main doctrines of Permaculture would be to minimize human labour and energy input while striving for no-waste agriculture and establishing a high level of synergy within the system with maximum productivity levels.

Twelve Permaculture design principles were developed by David Holmgren first in his *Essence of Permaculture in 2002*, prior to his book *Permaculture: Principles and Pathways beyond Sustainability,* now widely available on the website Permaculturepriciples.com (135):

1. *Observe and interact*: By taking time to engage with nature we can design solutions that suit our particular situation. Or the *"Beauty is in the eye of the beholder"* which explains that there is no right and no wrong in nature, just differences.
2. *Catch and store energy*: By developing systems that collect resources at peak abundance, we can use them in times of need. Permaculture sometimes relies on sustainable architecture to a great degree, and the more one researches Permaculture the more one realizes the unbreakable bond between the two, as in this principle of storing energy, described through sustainable cutting of forests, managing the heating source within houses, house design itself, and many other related subjects.
3. *Obtain a yield*: Ensure that you are getting truly useful rewards as part of the work that you are doing.
4. *Apply self-regulation and accept feedback:* We need to discourage inappropriate activity to ensure that systems can continue to function well. A bit theatrical is this saying published on their website goes a long way towards clarifying their philosophy: "The sins of the fathers are visited on the children unto the seventh generation," or what goes for our generation is that we now must rebuild what our grandparents have destroyed.
5. *Use and value renewable resources and services*: Make the best use of nature's abundance to reduce our consumptive behaviour and dependence on non-renewable resources. Now when enough is enough.
6. *Produce no waste*: By valuing and making use of all the resources that are available to us, nothing goes to waste with catchy slogans like these: *"A stitch in time saves nine." "Waste not, want not."* Are getting noticed around the organic community, not only in Permaculture.
7. *Design from patterns to details*: By stepping back, we can observe patterns in nature and society. These can form the backbone of our designs, with the details filled in as we go, to design food growing systems for life.
8. *Integrate rather than segregate*: By putting the right things in the right place, relationships develop between those things and they work together to support each other. Maybe one of the most applicable sayings concerning Permaculture is *"The whole being greater than the sum of the parts."*
9. *Use small and slow solutions*: Small and slow systems are easier to maintain than big ones, making better use of local resources and producing more sustainable outcomes.
10. *Use and value diversity*: Diversity reduces vulnerability to a variety of threats and takes advantage of the unique nature of the environment in which it resides. Applicable to nearly all the world's economies: *"Don't put all your eggs in one basket"* is used in Permaculture as well to accentuate the importance of diversifying your income.
11. *Use edges and value the marginal*: The interface between things is where the most interesting events take place. These are often the most valuable, diverse and productive elements in the system.
12. *Creatively use and respond to change:* We can have a positive impact on inevitable change by carefully observing, and then intervening at the right time. As *"Vision is not seeing things as they are but as they will be,"* this deeply

reflects present author's belief that one day in hundred years" time children will play in a deep shadow forest of former Saharan desert in the south of Egypt.

These principles should serve as guidelines and inspiration when designing a Permacultural farm, garden or forest. They are used to show how things should be planned or planted, but each Permacultural design also follows and generally recognises seven layers of food forest. However, depending of the geographical location some practitioners are now including fungi as an eighth and wetland as the ninth layer and they are bound to be formed as more Permaculture spreads across the globe and takes on new ecosystems. It is essentially trying to biomimic the surrounding ecosystem and for the maximum of the human benefits. These basic layers are (136):

1. *The canopy*: the tallest trees in the system, this type can be observed in all types of natural forests. These large trees are dominant but usually do not saturate the area leaving patches barren of trees available for new growth and our next layer.
2. *Understory layer*: trees that prefer the damped light under the canopy.
3. *Shrub layer*: which could be formed by most of the berry bushes; a diverse layer of woody perennials of limited height that forms woody steams.
4. *Herbaceous layer*: Plants in this layer die back to the ground every winter, if winters are cold enough. They do not produce woody stems and many are considered to be culinary and medicinal herbs. A large variety of beneficial plants fall into this layer. They may be annuals, biennials or perennials and are usually self-proliferating herbs.
5. *Soil surface/Groundcover*: There is some overlap with the herbaceous layer and the groundcover layer; however, plants in this layer grow much closer to the ground, grow densely to fill bare patches of soil, and can often tolerate some foot traffic. Cover crops retain soil and lessen erosion, along with green manures that add nutrients androgenic matter to the soil, especially nitrogen, such as white clover.
6. *Rhizosphere*: The layer of root crops, the main components of this layer are the soil and the organisms that live in it, such as plant roots, fungi, insects, nematodes, worms, etc. Although a more recognised and older definition of this term that has been used in Permaculture is slightly different and refers to a thin layer of soil in direct contact with the roots of the plants, referring to it as the chemical space around roots (137).
7. *Vertical layer*: climbers or vines, such as kiwi, hops, runner beans and lima beans, and all different available creeper crop varieties.

As mentioned above there are two or more additional layers not observed with the "founders" definition of the layers, most likely as they are coming from semi-arid and arid Australia, but no less important even for such harsh climates:

8. *Mycelia/Fungal Layer:* Fungal networks live in healthy soils. This underground fungal network transports nutrients and moisture from one area of the forest to another depending on the needs of the plants and nutrient availability. It is an amazing system which we are only just beginning to appreciate. More and more research is being conducted on how mycelium helps build and maintain the quality of the soil; therefore, it is important for it to be represented here separate from the Rhizosphere or root crop layer.
9. *Aquatic/Wetland Layer:* Many natural forests have streams flowing through or ponds located somewhere within. There are a whole host of plants that thrive in wetlands or at the water's edge. There are many plants that grow only in water. To ignore this large list of plants is to leave out many useful species that provide food, fibre, medicinal properties, as well as animal feed, wildlife food and

habitat, compost, biomass, and may be the most important, along with water filtration through bioremediation (or phytoremediation). As Permaculture is intentionally designing gardens/ farms which incorporate water features, this ninth layer is an essential one. And as for this project alone this ninth layer is one of the recognised methods in desert greening (by planting biomass crops like Salicornia in seawater in natural depressions and along sea shores).

Aside from core values, principles and layers that are defined by Permaculture, the Forest-garden recognises four zones based on a frequency of use. These zones represent a way of organising design elements in a human environment on the basis of the frequency of human use together with animal and plant needs. Frequently used or harvested elements of the design are located close to the house in zones 1 and 2. Less frequently used or manipulated elements, and elements that benefit from isolation (such as wild species) are farther away. Zones are about positioning things appropriately, and are numbered from 0 to 5.

Zone 0

Or the location of the house; here Permaculture principles would be applied in terms of aiming to reduce energy and water needs, harnessing natural resources and generally creating a harmonious, sustainable environment for the occupants. This zone provides opportunities to incorporate sustainable architecture and Permaculture, putting an accent on zero and plus energy houses, that could, depending on location, integrate zone 0 and 1 with IBTS-Greenhouses, vivariums or seawater greenhouses.

Zone 1

The zone nearest to the house, is location designated for those elements in the system that require frequent attention, that need to be visited often, nurturing crops such as salads, herbs, berries like strawberries or raspberries, greenhouse and cold frames, propagation area, worm compost bin and kitchen waste, etc. Raised beds are often used in zone 1 in urban areas.

Zone 2

This area is used for siting perennial plants that require less frequent maintenance, such as occasional weed control or pruning, including currant bushes and orchards, pumpkins, sweet potato, squashes etc. This would also be a good place for beehives, larger scale composting bins, and so on.

Zone 3

The zone 3 is where the main-crops are grown, both for domestic use and for trading/ selling. This is a great place for the Forest garden, nut trees, ponds, dams and similar, the main characteristic should be that after establishment, the needed care and maintenance are fairly minimal, like mulching, watering or weed control maybe once a week depending on climate.

Zone 4

This zone is considered a semi-wild area. Zone 4 is mainly used for forage and collecting wild foods such as mushrooms or for production of timber for construction and firewood.

Zone 5

A wilderness area often visited but only for observation and learning of natural ecosystems and cycles, there is no human interference in zone 5. Through this zone we build up a natural reserve of bacteria, moulds and insects that can aid the other zones.

However these zones are not strictly divided by any boundaries or borders, the zoning system naturally develops on the property intertwining and growing harmoniously, connecting everything into a holistic ecosystem. The boundaries that develop are minimal and only serve to enhance the productivity of the system, like the edge effect.

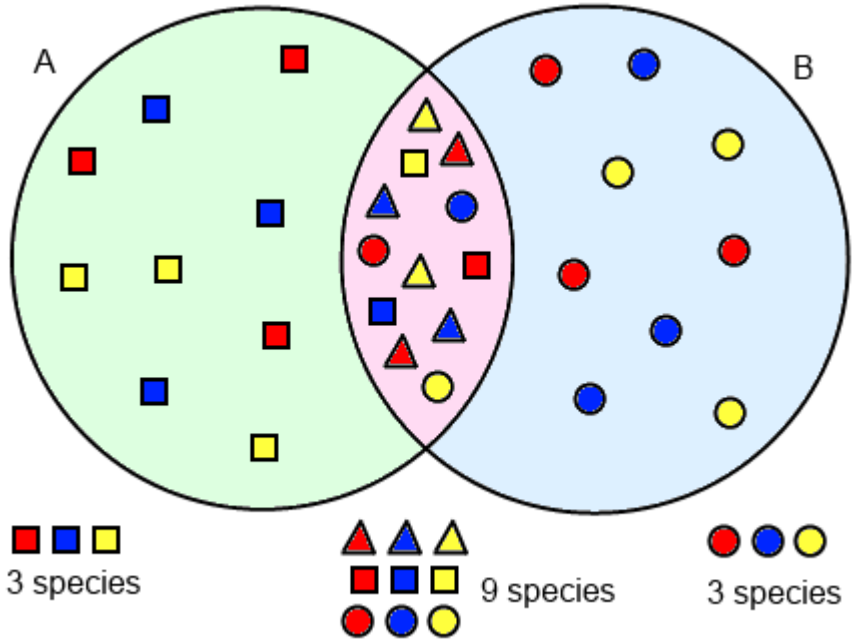

Figure 72. The "edge effect" – Where two ecosystems overlap, the overlapping area supports species from both, plus another species that is only found in the overlapping area (138).

In Permaculture books there has been a lot of talk on *the edge effect*. The edge effect mostly described as the boundary, perimeter of the controlled farm/garden/forest which if designed properly contributes to the biodiversity and enhances the overall productivity of the system, is actually know in ecology as the effect of the juxtaposition or placing side by side two contrasting environments of two ecosystems. In ecology this edge effect is observed in numerous accounts, where the sea meets the shoreline, where the forest meets the grassland or meadow, where a river meanders through a valley, typically wherever two contrasting environments collide a new ecosystem with species present in both and some new ones present only in this edge area are formed. This naturally enriches the biodiversity and helps resilience and might be where the answer to combating the Climate Change might be in ecosystems, full of diversity and naturally more resilient to extremes. Permaculturists also argue that where vastly differing systems meet, there is a diverse area of productivity, useful connections and abundance of life, meaning an ultimate increase in yields. That is why they accentuate the importance of increasing the edge effect through various patterns present in nature: wavy, curvy. An example of such Permacultural design is in using spirals in the herb garden or creating ponds that have wavy undulating shorelines rather than a simple circle or oval (thereby increasing the overall surface of an edge for a given area).

This type of planning will naturally be present in desert Permacultural gardens-farms. Firstly, so as to prevent sand storms overtaking the land, the boundary will have to be very diverse, especially in the later years when it will not be relying on solar panels for

protection, but this effect will be beneficial for our design as it will allow for the growth of our system and for the undisturbed life of desert wildlife.

A very interesting approach to conservational agriculture was developed by Sepp Holzer.

7) Sepp Holzer Permaculture and Hügelkultur

Holzer Permaculture as Austrian Josef Sepp Holzer (1942-) calls his approach to farming has developed relatively independently from the international Permaculture community. Born and raised on his family farm, Krameterhof, in the Province of Salzburg Austria, Sepp started experimenting with different agricultural practices. His approach to farming developed on a basis of trial and error which had formed on a long term observational study of farming in high altitudes 1100-1500 AMSL. As his knowledge grew so did his farm from 24 to 45 hectares, that now includes over 70 ponds of harvested rain water. The quick-witted Austrian rebel farmer quickly adopted beneficial practices, such as using the passive solar heating of the surrounding structures from ponds, and *Hügelkultur* historically used in German, Slavic and east European cultures for hundreds of years to provide nutrient rich and warmer soil.

There are not so many observable differences in the two approaches one being *Permaculture* and the other *Holzer Permaculture*. Holzer however has to use heavy duty machinery to form terraces on his farms slopes, but most of the time he relies on human and animal labour. As he had experimented with animals throughout his life he has a lot of witty interesting tasks for them, like using pigs to do the ploughing for him. He does not use any fertilisers and he does not prune his trees to make them more resilient to harsh winter conditions present in his food forest. He has successfully created an independent microclimate that grows even kiwis in a climate of a yearly average of 4°C and wintrily of -20°C! For planting trees that are not suited for such climates he was fined and even threatened with prison by Austrian authorities, earning him the nick name of a *rebel* farmer.

This is by far the most consistent example of Permaculture in the world, and a great example that shows that microclimate changes are possible with enough knowledge and dedication, a lecture that should be taken for afforestation of the Sahara in any case.

Hügelkultur used a lot in Holzer Permaculture, now advocated by many other Permaculturists across the world, involving a soil-enhancement process. Hügelkultur is a German word meaning mound culture or hill culture. Hügelkultur is made by piling up wood, old wood or decomposing wood, braches, composting materials, mulch and compostable biomasses and the pile is then covered, usually with upside–down turned grass that adds to the process of biodegrading making it in that way a very fertile mix. The process of making this kind of raised gardening beds, piles, improves soil fertility, water retention and warms up the soil, providing beneficial nourishment for the plants to grown on or near such mounds. In essence Hügelkultur replicates what is happening in the natural process of decomposition that occurs on forest floors. Trees that fall in a forest often become nurse logs decaying and providing ecological facilitation to seedlings. As the wood decays, its porosity increases allowing it to store water like a sponge. The water is slowly released back into the environment, when needed benefiting nearby plants.

Mounded Hügelkultur beds are ideal for areas where the underlying soil is of poor quality or compacted. They tend to be easier to maintain due to the fact that they are built up relatively high above the ground. The beds are usually about 1-2 m in width, of desired length and about 1 m height. Although their construction is very easy and straight forward, planning is necessary to prevent steep slopes that would result in

erosion. Some Permaculture designs recommend that mounds have a grade of between 65 and 80 degrees. In his book *Desert or Paradise: Restoring Endangered Landscapes Using Water Management, Including Lake and Pond Construction,* Holzer describes his method of constructing Hügelkultur. The design incorporates cardboard, clothes and kitchen waste. He recommends building mounds that are 1 meter wide and any length. Mounds are built in a 0.7 meters trench in sandy soil, and without a trench if the ground is wet.

Save Bhaskar unknowingly, from what was observed in available online documents from his farm such as videos and his farm website, also uses Hügelkultur in a tropical belt. This became of the interest as he uses the fallen coconut palm trunks to make little slopes and to separate his crops, but of greatest importance is that this is a way that provides his plants with enough water when the dry season arrives, allowing his farm to be lush green when everything in the surroundings turns to desert.

I would conclude that using wood in making wood-sponge-water-retention beds should be a practice that should be incorporated into common desert agriculture whenever excess wood of any quality is available.

8) FAO Save and Grow

The Food and Agricultural Organisation of United Nations, through a series of studies that monitored and advised many governments across world, made their action plan into a conservational agricultural approach to help make the Sustainable Development Goals of United Nations achievable (especially goal number 2., 13. and 15.) such as to combat the climate change while feeding the predicted 9 billion people by 2050.

*All the data acquired from the FAO Save and Grow (139)	World population in billions		
	3.3	6.9	9.2
Cereal production in billions of tons per year	1	2.2	3.4
Calendar Year	1960	2010	2050

Figure 73. World production of cereal 1960, 2010, 2050

The main concept of this approach argues that the cereal production that had since the start of the green revolution followed the growth of population from 1 to 2.2 billion tons of cereal, will have to change from business as usual model if we are to experience less than + 4°C degree temperature increase in this century. To ensure that this does not become reality FAO suggests that in order to grow the agriculture must first learn how to save, hence save and grow the name of the approach and book publicised by FAO.

FAO bases its *Save and Grow* eco-friendly, conservational agricultural approach on following seven pillars presented on their website (139):

1. The challenge

In order to feed a growing world population, farmers will be forced to intensify crop production, although they will be faced with unique and unprecedented constraints that will come with Climate Change, including increased soil fertility loss and degradation,

water and fossil fuels shortages, and many others now unaccounted for. Therefore, in order to grow, the agriculture of the 21st century must learn to save, using the new paradigm Sustainable Crop Production Intensification SCPI.

2. Farming systems

Crop production intensification will be built on farming systems, similar or identical to previously described ones, which offer a range of productivity, socio-economic and environmental benefits to producers and to society at large.

3. Soil health

Agriculture must, literally, return to its roots by rediscovering the importance of healthy soil, drawing on natural sources of plant nutrition, and using mineral fertiliser wisely. Soils rich in biota and organic matter are the foundation of increased crop productivity.

4. Crops and varieties

Farmers will need a genetically diverse portfolio of improved crop varieties that are suited to a range of agro-ecosystems and farming practices, and resilient to climate change. Over the past century, about 75 per cent of plant genetic resources (PGR) have been lost and a third of today's diversity could disappear by 2050. Increased support to PGR collection, conservation and utilisation is crucial. Funding is also needed to revitalize public plant breeding programmes. Policies should help to link formal and farmer-saved seed systems, and foster the emergence of local seed enterprises.

5. Water management

Sustainable intensification requires smarter, precision technologies for irrigation and farming practices that use ecosystem approaches to conserve water.

6. Plant protection

Pesticides kill pests, but also pests" natural enemies and their overuse can harm farmers, consumers and the environment. The first line of defence is a healthy agro-ecosystem.

7. Policies and institutions

To encourage smallholders to adopt sustainable crop production intensification, fundamental changes are needed in agricultural development policies and institutions.

The approach is based on conservational agriculture and in many aspects it follows the guidelines of old permanent agricultural methods that were widely adopted before the Green Revolution as well as the current Permacultural and similar approaches. The FAO makes a clear distinction between an interventionist approach or conventional agricultural approach as described here, and the ecosystem approach that nurturing the soil and biodiversity enhances the farmers" yields. This new approach by FAO is called a sustainable crop production intensification method or SCPI and it offers socio-economic and environmental benefits to producers, adaptation and reduced vulnerability to climate change, enhanced ecosystem functioning and reductions in agriculture's greenhouse gas emissions and carbon footprint of agriculture as a whole. Their farming approach mainly relays on this seven principles of conservational agriculture which are: to minimise the soil disturbance, conservation tilling or minimal to no till, enhance and maintain organic soil cover, no monocropping, more bio-diverse planting, native or

naturalised high yielding seed varieties, enhanced crop nutrition which does not exclude inorganic fertilisers, integrated pest management and efficient water management.

This FAOs approach is a balanced version of two very contrasting worlds of conventional agriculture and conservational agriculture, this approach makes a system of guidelines that can be adapted and further developed and enhanced in various countries and to suit their local needs and levels of development, but with an accent to soil preservation and conservational agriculture, making sure that in order to grow agriculture of 21st century we will have to learn how to save on using heavy machinery, pesticides, herbicides and generally learn how to lower the environmental impact the green revelation has broth up and go back to the roots of permanent and conservational agriculture, providing a sound benchmarking system widely applicable, although not organic.

9) Organic agriculture

"Organic" produce appears to be hackneyed phrase in everyday talk, usually related to ex-hippie communities, communes, hysterical over protective parents and hipsters, having the reputation of being overpriced and overrated. They are a growing source of debates between scientific communities, between farmers, countries and federations such as European Union with 27 % of world's organic farms, and many of on-going studies. So much so that it has been a cause of subtle disagreements between the two of the United Nation departments, the FAO and the UNEP. So much so that the FAO decided to develop its own approach to sustainable farming while UNEP continues to push for organic agriculture to be developed with its international and national partners by organising national workshops and similar activates to support it. There have been theses published on the contribution of organic agriculture to the environment and to climate change on its relation to conventional agriculture. There are studies older than me that are still on-going, such as the ones on the comparison of different approaches in organic agriculture in comparison to themselves and to conventional agriculture and many more newly published ones.

These are often the on relation of free range organically grown animals and methane and nitrogen release into the atmosphere and its relation to climate change; due to all of this fact the author is of an opinion that the more comprehensive introduction into organic agriculture is not needed as it is widely available online, there will be only a short overview here with reflecting upon the differences not between the conventional agriculture and organic one, but between the organic agriculture and Permaculture and other conservational approaches, as the overwhelming array of studies developed on the subject of organic vs conventional agriculture were convincing so full heartedly that I am of belief that there is no need to research into the benefit of organic agriculture any further as they should be set as bare minimum in all the conservational approaches to agriculture.

Organic agriculture is the biggest, maybe one of the most well defined and regulated approaches of all who oppose conventional agriculture. Organic agriculture is a certified system approach to agriculture and farming governed by International Federation of Organic Agriculture Movements IFOAM and the bodies they have certified in individual countries. It has many aspects in common with previously described approaches such as conservational approach to agriculture, holistic management, strongly opposes genetically modified organisms, artificial pesticides, herbicides, fungicides and all the other artificially produced chemicals that are in use in conventional agriculture and although it has been supported in many of the mentioned approaches or being part of them. It has led its own battle for recognition since its official founding in 1972 in Paris.

One of the founders of organic agriculture movement was Lady Eve Balfour, who said that the characteristics of truly sustainable agriculture can be summed up by the word "permanence" hence the similarity to Permaculture which will be analysed.

It is also the most scientifically researched of all of the above mentioned approaches, with some long term studies being older than 30 years such as the one from the Rodale Institute.

The definition provided by the IFOAM on what is organic agriculture is as follows (140): "Organic Agriculture is a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic Agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved."

In short an organic agriculture system has four main principles as described by the IFOAM (140):

1. The Principle of Health

Organic Agriculture should sustain and enhance the health of soil, plant, animal, human and planet as one and indivisible. This principle points out that the health of individuals and communities cannot be separated from the health of the ecosystems, healthy soils produce healthy crops that foster the health of animals and people.

2. The Principle of Ecology

Organic Agriculture should be based on living ecological systems and cycles, work with them, emulate them and help sustain them. This principle roots Organic Agriculture within living ecological systems. Organic management must be adapted to local conditions, ecology, culture and scale. Inputs should be reduced by reuse, recycling and efficient management of materials and energy in order to maintain and improve environmental quality and conserve resources.

3. The Principle of Fairness

Organic Agriculture should build on relationships that ensure fairness with regard to the common environment and life opportunities. Fairness is characterized by equity, respect, justice and stewardship of the shared world, both among people and in their relations to other living beings. This principle emphasizes that those involved in Organic Agriculture should conduct human relationships in a manner that ensures fairness at all levels and to all parties - farmers, workers, processors, distributors, traders and consumers. This principle insists that animals should be provided with the conditions and opportunities of life that accord with their physiology, natural behaviour and well-being.

4. The Principle of Care

Organic Agriculture should be managed in a precautionary and responsible manner to protect the health and well-being of current and future generations and the environment.

These four main principles of Organic Agriculture already bring similarities with Permaculture and its earth care, people care and fair share ethics. Alongside with these caring values are as well limiting aspects for the production and processing of organic products which include (141): strict limits on chemical synthetic pesticide and synthetic

fertiliser use, livestock antibiotics, food additives and processing aids and other inputs, and absolute prohibition of the use of genetically modified organisms (GMOs). Organic agricultural approach uses majority of recognised conservational approaches such as: crop rotation, taking advantage of on-site resources, livestock manure for fertiliser, choosing plant and animal species that are resistant to disease and adapted to local conditions, raising livestock in free-range, open-air systems, using animal husbandry and etc. Organic agriculture market is estimated to be worth more than 55 billion euros in 2015; with all the cut costs on fossil fuel and petrochemicals alone together with the premiums added one can easily see the benefits of switching to organic agriculture especially in countries such as European Union that subsidises this kind of agriculture. While the benefits for the consumers are more in self and environmental help, the benefits for the farmers are, aside from self-help, monetary. However, many problems have aroused from farmers and agribusinesses switching to organic agriculture from solely monetary interest. Most of the critiques addressed towards organic approach are pointing into this direction, when organic agriculture is used only partly being adopted, with the old conventional agriculture based thinking of doing business, as this is only when in organic agriculture over spraying and over use of land are present. But these are mainly isolated cases as the conventional organic farmer aims to use no chemicals whatsoever, and its yields are gradually building up trough years, as proven in Switzerland long-term-study of 21 years.

In developed world organic agriculture practices shows an average only 13 % less yield than conventional, but more in importantly for this study, in developing world where poor and most of the worlds" hungry live, and where this project is situated choosing an organic approach actually increases yields by 93 % on average (142). Knowing that conventional agriculture inputs are not affordable by the majority of farmers dwelling there, organic agriculture can play an important part of increased food security. This hypothesis was supported the United Nations Environmental Programme (UNEP) and the United Nations Conference on Trade and Development (UNCTAD) that stated: "organic agriculture can be more conducive to food security in Africa than most conventional production systems, and that it is more likely to be sustainable in the long-term" and that "yields had more than doubled where organic, or near-organic practices had been used" and that soil fertility and drought resistance improve significantly (143). This goes along with what had the Asian Development Bank Institute study on the costs of Organic Agriculture programs and their variability in price, and all in relation of the costs per person taken out of poverty, which they found depends the most on the efficiency of the Organic Agriculture adoption programs. However, further analysis of the gains resulting from Organic Agriculture adoption reveals that the costs per person taken out of poverty was much lower than the estimates of the World Bank, based on income growth in general or based on the detailed costs of meeting some of the more quantifiable Millennium Development Goals.

Benefits of switching to organic agriculture are numerous but what are the exact differences in organic approaches in comparison to our previous approaches especially to Permaculture, as there is an abundant amount of research that appears to see them as equal? They both practice conservational agriculture, meaning restoring the ecosystem of the soil and the surroundings, hence they both use regular conservational methods in achieving so, but what is the difference? For me the biggest difference is in the approach to agriculture itself, namely organics approaches agriculture as dose the conventional, something in lines of this is going to be my hard job, that needs to be done every day, every year it is very hard work and the difference with conventional which did not require knowledge organic does have knowledge intensive base, while on the other hand we have Permaculture that approaches agriculture in a way like, hey

let’s enjoy our time together I help you, you help me, purposefully planning so that the least amount of work is needed, making sure to plant the smallest amount of annual crops possible if any.

Therefore, the biggest difference is in the crops they plant, annual opposed to biannual and perennial more likely, hardworking approach versus lazy approach. One more similarity to conventional agriculture in organic agriculture is the planting of monocropping cultures; although in organic agriculture farmers are encouraged to use crop rotation, winter crop and legumes, white clover, green manure and animal manure they are still technically allowed to plant monocrop fields that need to be tilled at least once a year, hence lowering the soil ability to capture CO2. Permaculture uses minimum soil disturbance approach to no-till, meaning its” soils CO2 capturing ability is higher than organic approach. This would be a second important difference till opposite minimum to no-till system. Permaculture relays on inter cropping, integrated cropping, alley cropping, beneficial weeds and companion planting, this is a third important difference the way they plant crop rotation as oppose to crop integration.

Then there is the question of crop protection where the list of allowed organic chemicals to be used as fungicides, pesticides, herbicides, and fertilisers is very long, as opposed to Permaculture which strives to develop an ecosystem that will be resilient enough to provide benefits for the farmer as well as for the pests. Organic agriculture lowers the use of heavy machinery a lot in comparison to conventional agriculture, but it is still present a lot when compared to Permaculture which relies more on people and animals. Also very important difference is observable in irrigation practices, where organic agriculture uses conventional irrigation approach, and Permaculture tries to use mulching, Keyline and other techniques to prevent evaporation and the need for constant irrigation and dependence on the network in the first place.

To conclude that although the two have similarities they have noticeable differences too, not meaning one is better than the other, but more that one is more suited for the desert that the other. Also important is the acceptance and support that the organic approach has gained in mainstream science and within the developmental agencies such as the UN bodies, this is something towards what the Permaculture should strive to, but also something that it could use to its benefits, making sure that all the farms are registered as organic as soon as they start to develop; there is no reason why the two should be mutually exclusive, when they support and have the overlap of main targets example are the farmers and people who practise them as well as all the other named approaches have the health of environment and people in their heart first, this is why they should work towards being better individually but also relying and adopting the beneficial approaches from each other.

Chosen method: the conservational agricultural approach to desert greening

Chosen method: the conservational agricultural approach to desert greening

Name of conservation agricultural approach ↓	Unique characteristics of the approach	**Positive characteristics of the approach**																									Negative characteristics of the approach	
		Minimum soil disturbance	No-tillage	Permanent organic soil cover	Biodiversity enhancement	Animal husbandry	Poly-culture	Companion-planting	Keyline design *	No-waste	No chemicals	Clay seed balls	Restoration of soil biota	Holistic approach	The use of high yielding varieties from good seeds stock	Integrated pest management	Planning nutrient additions based on soil testing	Efficient water management and irrigation	Crop-pasture integration	C-A Conservational agriculture	Agroforestry or incorporating some type of trees planting into approach	Organic farming	Allan Savory Holistic Management System	Proven efficiency in Desert greening	To restore, maintain and enhance ecological diversity of the farm	The use of GMO out of controlled laboratory conditions	Unique negative characteristic
Save & Grow by FAO UN		+	-	+	+	+	-	-	-	-	-	-	+	+	+	+	+	+	-	+-	-	-	-	+	-	+	
Organic by IFOAM		+	-	+	+	+	-	+	-	-	-	-	+	+	-	-+	+	-	-	+	-	+	-	+	+-	-	
Ecoagriculture	**Sees landscapes as a unit of measurement**	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	-	+	+	+	+	+	+-	+	+	-	
Agroforestry food-forest forest-garden	**Combining forests with food produciton**	+	+	+	+	+	+	+	-	-	-	-	+	+	-	-+	-	+	+-	+	+	+	-	+	+	-	
Do nothing farming M.F.	**Clay seed balls;** No cultivation - no ploughing, no tilling, zero tillage or direct drilling No chemical fertilising or preparing compost No weeding by tillage or herbicides No dependency on chemicals Pruning of trees is unnecessary	+	+	+	+	+	+	+	-	+	+	+	+	+	-	+	-	+	-	+	+	+	-	+	+	-	To strict guidelines and to hard transitioning period
Permaculture	**Boundary edge effect**	+	+	+	+	+	+	+	+	+	+	-	+	+	+-	+	-	+	+	+	+	+	+	+	+	-	Surrounded by hippy culture
Holzer Permaculture	**Hügelkultur decomposing wood**	+	-	+	+	+	+	+	+	+-	-	-	+	+	-+	+	-	+	-	+	+	+	-	+	+	-	Presence of heavy machinery
Biodynamic farming	**10% rule of a biodiversity reserve** (1) by which every farm has to put aside 10% of their land and put it into use of nature preservation. Make it into a forest, wetland, or similar depending of the natural surroundings of the farm	+	-	+	-+	+	+	+	-	+	+	-	+	+	-	-	-	-	-	+	-	+	+-	+	+	-	The spiritual, mystical and astrological part by which this approach is known
New approach		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	

Figure 74. Conservation agricultural approaches and the unique, positive and negative characteristics

Looking at this table a clearer image can be gained on the scale of conventional-conservational agricultural approach, as it is clear that Save and Grow by FAO is the closes to conventional agriculture while Biodynamic would be the furthest away, but unfortunately also the furthest away from any scientific approach too. Taking the most important bits from each my conservation agricultural approach to greening the Sahara Desert in Egypt successfully is based upon all of the above approaches and recognised desert greening approaches into a single unified approach best suited for Egypt's conditions. Viewed from the Agroecological point of view as this "approach" is actually a system for observing the approaches and measuring and counting them validly, this is the stand point that I take in; agroecology which will enable for any future adaptations and changes and a clear scientific approach based on measurable data, proven success practices and policies. Some older approaches that were adopted throughout many different approaches characteristically put in as they became widely adopted such as Keyline design, Polyculture, clay seed balls, while as genetically modified organisms were widely unaccepted and the available data coming from independent sources is not sufficient to draw any conclusion in direction of their use in free ecosystems, the decision is made for them to be entirely excluded until further research is available. The approach would appear to be the following: while keeping in mind the care for the people, environment and economic feasibility as key principles, the approach would be the most similar to Ecoagriculture and Permaculture, and having the agroforestry as a key field of profit so the majority of the land would be turned into forests governed by the rules of Ecoagriculture and Permaculture, while obeying the rules of IFOAM and registering all the produce under the strict rules of organic agricultural movement, as it is already clear that the IFOAM had set the rules very clear and concise for the farmers to follow, while some might develop in other directions I am of belief that it is of utmost importance to register as organic producer if you belong to any of this agricultural approaches as the organic know represents a solid base from which to start building a healthy and sustainable agricultural systems for the future. Focus on no-till system should be accentuated as in the desert conditions the actual building of the soil is crucial for project progress, keeping the permanent organic soil cover throughout the year will not only add to the increase of soil organic matter but also effectively prevent increased rates of evaporation present in the desert.

Biodiversity enhancement will be present through using the Permacultural approach to planting diverse species, with tendency to always use local and high adapted varieties with high yields and high tolerance to drought, while planting them in no less than seven forest layers. Included in this approach will be animal husbandry and Allan Savory's Holistic Management System for grazing the cattle, using again species that are native or already adapted to high droughts. Polyculture and companion planting are also one of the integral parts of this approach as these separate approaches have been so widely accepted that are put here in characteristics even though they are considered separate approaches.

Keyline design will be used not so much to harvest the rain water but to retain the excess water from irrigation and will be used in conjunction with the Holzer Hügelkultur beds made of available wood material if any, if not with the newly trimmed branches of Moringa Genus trees, as their trimming will help sprout the life in their roots with bacterial and beneficial microorganisms. In order to be productive in the desert there will be no space for waste as every single bit of the plants and animals must be used to enhance the soil organic content. In this context of enriching the soil in certain locations the clay will be widely available and in these locations the use of clay seed

balls should be encouraged, as the clay content in the soil has been proven to increase the soil fertility especially in deserts making the soil more drought resistant.

Taking in the conservational approach wholeheartedly some of its characteristics are based on FAOs Save and Grow approach as it has three valid points. Using the high yielding varieties from a good seed stock will enable the initially sprout, but farmers will be encouraged to preserve their own seeds and to use their own varieties but with the knowledge and the ability to use the previous ones as well. Integrated pest management system present in Permaculture as well is an important factor to no chemicals method, as well as is the planning nutrient addition based on soil that has been previously tested so to know what actual additives are needed and which plant can provide them. In the alley cropping parts of the agroforestry system as well as in all the available newly produced grassland the crop-pasture system will be encouraged as not one practice adopted should serve a single purpose in this complex but yet very simple approach that strives to be self-sustained in 100 years" time overtaking the whole of the Sahara Desert.

With new evidence recently found in Chad which dates the Sahara Desert all the way back to 7 million years ago (Schuster et al, 2006), the oldest age estimates for its current range to the west are around 2.5–6 million (Swezey, 2009; Ruddiman et al, 1989; Tiedemann et al, 1989) (144). However, we are now more than ever certain that Sahara has, during these 7 million years, always oscillated between the desert that it is and the Sahel, a savannah like climate. Yet we are now more than ever certain of the times when there was a total prevail of Sahel, the times in Holocene era when the Sahara was completely defeated. With this knowledge taken into account and if we look at all the recognised methods present in desert greeting across the world and combine this knowledge with this conservational approach to agriculture together with having our pipeline system for soil formation and irrigation, all the while knowing these prehistoric facts about the Sahel-Sahara shifts, there is a great opportunity to make a change in the right direction and reverse the climate change altogether with providing the people food security and healthy lifestyle. There is no place for mistake. The approach advocated in this work already greatly supports and/or includes some of the following of desert greening approaches:

Recognised methods in desert greening (145):

1) Managed intensive rotational grazing
2) Holistic management- Allan Savroy
3) Landscaping methods to reduce evaporation, erosion, consolidation of topsoil, sandstorms, temperature and more
4) Permaculture in general - harvesting runoff rainwater to grow plant communities Polyculture, composting or multitrophic agriculture
5) Planting trees (pioneer species) and salt-loving plants such as Salicornia and Halophytes
6) Regeneration of salty, polluted, or degenerated soils regenerative agriculture and conservational approaches
7) Floodwater retention and infiltration (flood control)
8) Greenhouse agriculture like the Integrated Biotectural System
9) Seawater farming like done by the Seawater Foundation
10) Inland mariculture
11) Prevention of overgrazing and firewood use in direct opposition to second approach of Allan Savroy
12) Training of local residents to care for plantings, water systems etc.

13) Planting trees with dew and rain harvesting technology like the Groasis Waterboxx or Liquid NanoClay and many other individually developed technologies

Integrated into this conservational approach are six of the 13 recognised desert greening approaches, such as different landscaping and technical methods to reduce evaporation, erosion, consolidation of topsoil, and prevention of sandstorms overtaking the newly formed land as well as their greater development in the region. The approach itself is the closest to Permaculture and relies on all of its recognised methods in desert greening, while also lowering the local temperature by introducing the clay rich silt troughs the pipeline, harvesting runoff rainwater- although in this case reusing the irrigation water in multiple cycles to grow Polyculture in multitrophic agriculture scheme present in Permaculture designs. While planting pioneer tree species such as Moringa Genus and salt-loving plants such as Salicornia and Halophytes. Also included are the regeneration of salty, polluted, or degenerated soils specifically in the area of current Toshka project thought regenerative agriculture and other conservational approaches. A great social belief that only through training (as proven by the NGO NCBA CLUSA (97)) of local residents to care for plantings, for trees, and water systems to see the value in planting trees we can make a difference. Together with applying advanced technologies and many other individually developed technologies for planting trees in the desert this problem can be addressed properly.

This approach hopes to open the door of desert greening and to set the standards to all available and new approaches in conquering the desert. There is enough of desert available across planet for all of these approaches to be tested on multiple applications and variations, starting with the approach described in this thesis together with Permaculture and the holistic management by Allan Savroy a historically based model of grazing the animal in desertified lands with 100 % success rate on all five continents. While desert greening will provide direct benefits to the people living there it will enable us living far away to sequester CO2, *as turning desert to green land lowers the surface temperature around 15°C and reduces CO2 emissions by 15-25 tons per hectare*.

This afforestation project is quite unique in itself, partly due to the sustainable transportation system that has been proposed here, to use in its starting phase and as its irrigation later on, partly due to the different soil building plants that are proposed and due to the effect we want to achieve with them in further reading.

Africa native plants – The use of Moringa Genus in afforestation of the Sahara Desert and the relation with the UNs SDGs

Referring to SDG Goal: 2, 6, 10, 13, 15

Issue (Topic): Food security and Environmental sustainability

Figure 75. Women in Medo, Ethiopia, tending to Moringa cabbage tree seedlings (Moringa Stenopetala). Photo: www.un.org/africarenewal

ABSTRACT

Crucial to my research of "Making the Sahara Desert Green" is the use of species native or naturalised to North Africa, as they will be the least demanding, such as Moringa Stenopetala and Moringa Oleifera. This species has been hailed as the plant of the 21st century by the Food and Agricultural Organization (FAO) of the United Nations (UN), as a key plant to combat undernutrition and malnutrition in developing countries. All parts of the Moringa tree – the bark, pods, leaves, nuts, seeds, tubers, roots, and flowers – are edible, plus it is one of the fastest growing trees/shrubs in the world with growth of up to a staggering 12 metres a year! It is also quite a valuable species; in Vienna 100 grams of its ground leaf powder costs around 10 Euros. Moringa seeds have been successfully used to purify drinking water that becomes of greater quality than commercially treated water, and this is currently being studied at the University of Lausanne, Switzerland. Moringa has also been used to produce biofuel. This article will discuss of the SDG and their connection to using Moringa Genus in afforestation of Sahara Desert in Egypt.

Sustainable Development Goals and their relation to my work

My research on "Making the Sahara Desert Green" is closely related with the Sustainable Development Goals (SDGs) on multiple levels as it is cross disciplinary system design with integrated approach to afforestation. However, in this article I will only discuss at length the SDGs that relate to the part of my work that is dedicated to the use of the Moringa genus in afforestation, that is, in my research "Making the Sahara Desert Green".

List of SDGs[11]

Goal 1 End poverty in all its forms everywhere
Goal 2 End hunger, achieve food security and improved nutrition and promote sustainable agriculture
Goal 3 Ensure healthy lives and promote well-being for all at all ages

[11] (Sustainable Development UN)

Goal 4 Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all
Goal 5 Achieve gender equality and empower all women and girls
Goal 6 Ensure availability and sustainable management of water and sanitation for all
Goal 7 Ensure access to affordable, reliable, sustainable and modern energy for all
Goal 8 Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
Goal 9 Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
Goal 10 Reduce inequality within and among countries
Goal 11 Make cities and human settlements inclusive, safe, resilient and sustainable
Goal 12 Ensure sustainable consumption and production patterns
Goal 13 Take urgent action to combat climate change and its impacts
Goal 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development
Goal 15 Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
Goal 16 Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
Goal 17 Strengthen the means of implementation and revitalize the global partnership for sustainable development

SDG 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss

Figure 76. Certain desert fauna pictured in *Environmental Atlas*, www.environmentalatlas.ae

SDG 15.2 By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally

SDG 15.3 By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world

In a sense, the whole of my research on "Making the Sahara Desert Green" seems to be in response to this sustainable development goal, as the idea originated in the biomimicry approach and a desire to bring back to the nature, people and land what was and what is rightfully theirs: the rich Nile silt alluvium. Through my research, I will be building amongst other a sustainable terrestrial ecosystem to help combat desertification in the Sahel region and promote the formation of new arable land in the Sahara Desert. The research strives to achieve the stop and reverses the land degradation in the Nile Valley and delta region that has been degrading since the erection of the Aswan High Dam, as the changes in sediment transport and delivery have brought significant transformation in the delta-coast morphology. Strong erosion of coast line has occurred in recent decades, including coastline retreat and saltwater invasion. Many studies have reported degraded ecological environments in the lagoons, including increasing levels of heavy metals and nutrients, which have caused eutrophication, coming from the over use of fertilisers. Due to the fact that the alluvium, which once used to flood the Valley of Nile annually, is now trapped behind the Aswan High Dam, the farmers downstream are forced to use artificial fertilisers and contribute to further soil erosion. Soil salinity has increased due to the rise of groundwater table. A total of 2.1 million hectares thus required subsurface drainage at a cost that by some sources exceeded the construction costs of the High Dam. Only 20 years after the completion of the High Dam, the problem was seriously addressed and a large-scale drainage programme was initiated.

When applied, my research should reverse all these problems, as they all occurred initially due to a lack of building blocks. The silt, which will be brought back, should help to halt biodiversity loss in this already fragile desert environment and help disperse the terrestrial ecosystems of present day oases. To ensure that rare but yet present ecosystem of Sahara is not harmed bio bridges will be formed throughout the New Valley.

Planting the Moringa Genus in the desert as a native forest carrier species will allow for faster development and easier integration of the whole research.

SDG 13: Take urgent action to combat climate change and its impacts

13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries

13.2 Integrate climate change measures into national policies, strategies and planning

13.3 Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing states, including focusing on women, youth and local and marginalized communities

Geoengineering is defined as the deliberate large-scale manipulation of an environmental process that affects the earth's climate in an attempt to counteract the effects of Climate change.[12] Afforestation being one of many geoengineering techniques to combat Climate change is well established and defined. The FAO's Dieter Schoene states that for afforestation to have occurred proof must be given that the land being utilised was not forested for at least 50 years and that it consists of trees with a height of at least 2-5 m, a crown density of between 10-30 %, and an area between 0.05-1 ha.[13] Since the FAO does not define "tree", fruit trees, bamboos, palms and Moringa Genus may qualify. Afforestation and reforestation can consist of assisted natural succession to trees, productive and protective plantations, agroforestry, and urban forests.[14]

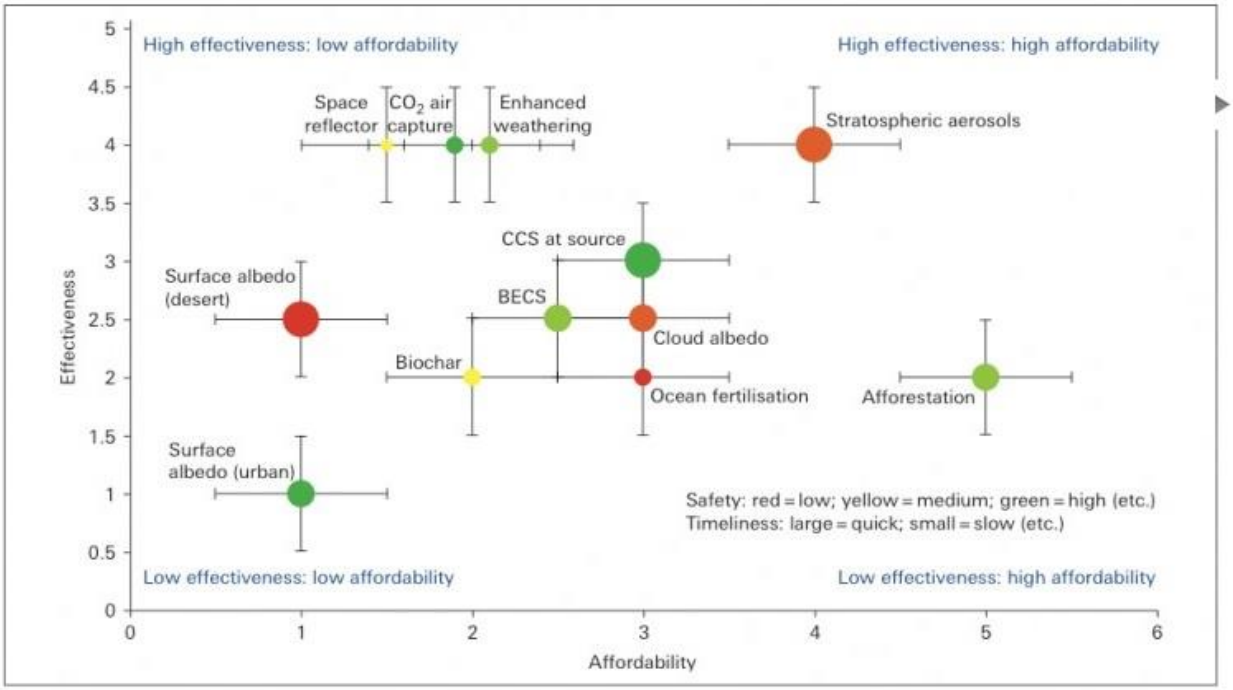

Figure 77. Evaluating effectiveness and affordability of geoengineering techniques. Chart from Oxford geoengineering programme, www.geoengineering.ox.ac.uk

Regarding this sustainable development goal, my project of "Making the Sahara Desert Green" is a direct response: by making new arable land covered with rows of Moringa genus trees I will be adhering to the FAOs regulations on afforestation and answering this call with direct action on climate change as I see afforestation to be the safest of all geoengineering techniques and one that will not just be answering the carbon capture question but also many other questions as side effects. I see afforestation to be a holistic approach to combat climate change and its impacts.

Using afforestation in especially in the Sahara Desert with Moringa Genus, we would also answer some of the biggest concerns when talking about afforestation such as albedo and the time frame. Namely Moringa being the desert tree already has a shade that is not deep green but very pale, silvery grey in colour and should have the same albedo; as for the time frame which is the main reason why afforestation is put on a slow side of geoengineering approaches, by using Moringa Genus we would be able to prevent such

[12] (Oxford)
[13] (103)
[14] Ibid.

long term waiting outcome as the Genus is amongst the fastest growing trees on the planet, which given the right circumstances can have up to 3 harvests per year.

SDG 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

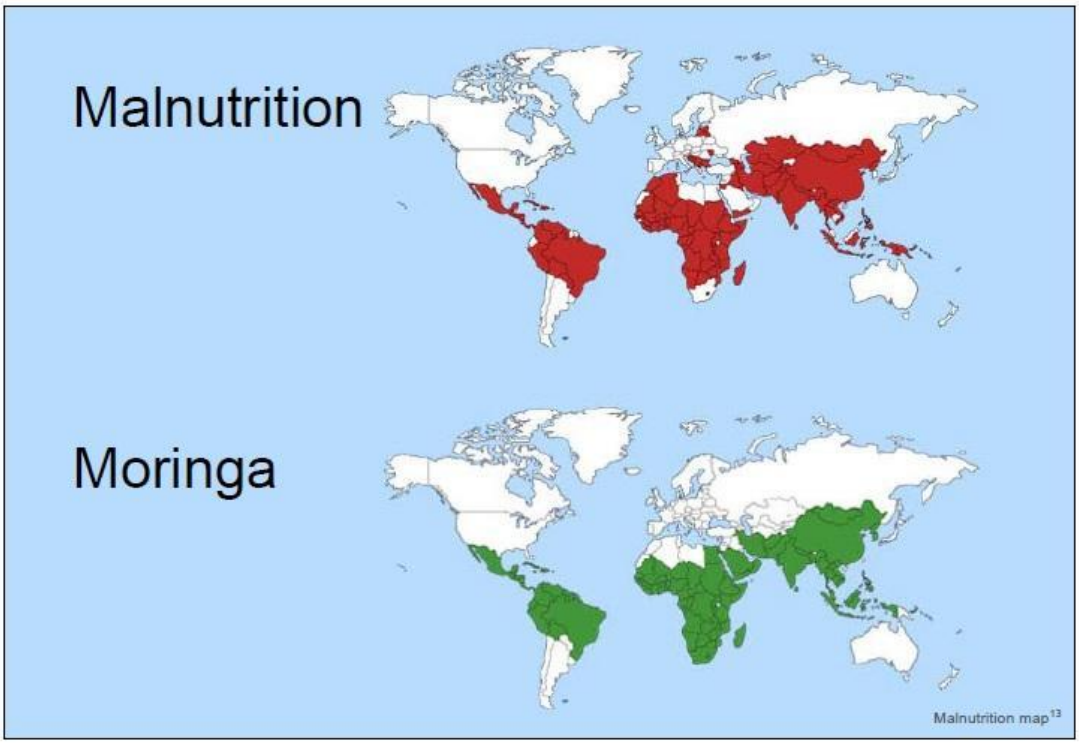

Figure 78. Congruence of Moringa-friendly environments and malnutrition. www.treesforlife.org

This ability of Moringa Genus to grow so fast comes as a response to the SDG number two. Part of my research on "Making the Sahara Desert Green" developed as an answer to the rising problem of food security in Egypt, Africa and the world as a whole, while the other part developed in response to the rising alluvium sedimentation behind the Aswan High Dam built on the river Nile in Egypt. Quality food and better nutrition in co-ordinance with sustainable consumption and sustainable agriculture is needed across the globe if we are to sustain our predicted population. Alongside urban-cropping, urban-forests, peri-urban agriculture, inter-cropping, agro-forestry, vertical agriculture and Permaculture, afforestation, in my opinion, will have to play a major role in providing food, as well as jobs for the growing population.

This is where the use of the Moringa genus comes in, in particular Moringa Oleifera, Moringa Stenopetala, and Moringa Peregrina. As one of the most nutritious plants on the planet, which cannot only survive in harsh desert conditions, but flourish, as it is its native environment, this species provides a wide variety of vitamins, minerals and essential amino acids, packed into its leaves, pods, tubers and all other parts of the plant.

Just by planting a Moringa genus tree/shrub in poor quality soil or sand we are doing something that goes beyond sustainability, if we were not responsible for depleting the land of its nutrients by mono-cropping for decades in the first place, as it enriches the soil tremendously, allowing for more demanding crops to be planted in the years to come. Therefore, this research goes beyond sustainability approach in "Making the Sahara Desert Green" as it is making new arable land (as the Moringa prefers poor

quality soil or sand and enriches it throughout its life cycle so that we get a healthy soil after certain period of time) on which we can exploit the plant, depending on the weather conditions, with harvests every second week as has been observed in Niger.[15]

Thus, planting Moringa trees/shrubs responds directly to the second SDG on ending hunger as the whole tree is edible and highly nutritious and will help to achieve food security and improved nutrition, especially in the countries of Asia, Africa and South America, where it is the most needed, while promoting not sustainable agriculture, but beyond sustainable agriculture, allowing for new agricultural lands to be developed and enriched with nutrients in areas affected by desertification and already existing deserts.

SDG 10: Reduce inequality within and among countries

Introducing the Moringa tree as a crop to Egypt, from where Moringa Peregrina comes from, will empower farmers as they will have the means to fight against inequality and poverty. By observing successful examples such as the NCBA CLUSA International's Moringa Oleifera project in Niger[16] as an example for reducing inequality and providing an opportunity for better standards of living, we should be able to transfer the knowledge gained through this project and implement it successfully in Egypt.

In their project "Moringa Intensification Project to Help Respond to and Mitigate the Drought Disaster in Niger" in the sector of food security and agriculture, they proved that Moringa is very useful in periods of prolonged drought, and essential to increased income. Among the highlights of the project is a story from 56-year-old Karimou Lamisi who increased her annual income by more than 400 per cent thanks to NCBA CLUSA and Moringa Oleifera harvests in the height of the dry season, which allowed her household of 12 to pay for animals, clothes for children, healthcare and to send them to school. Farmers on average experienced revenue increases of 298 %, while their profits increased 504 %.[17]

By empowering people to be in charge of their own lives and giving them the means to fight poverty we are reducing inequality within countries. For this particular farmer in Niger this means was Moringa Oleifera, and hopefully one day soon this plant will be a means of empowerment for the Egyptian farmer as well.

SDG 6: Ensure availability and sustainable management of water and sanitation for all

In my research I will be transporting alluvium rich water mixture through the Sahara Desert, by using pipelines which do not allow for any water loss and evaporation along the way; this is directly connected to this SDG of ensuring availability and sustainable management of water. Aside from this, the mere use of Moringa species, as they do not require constant irrigation and can go without a water supply for prolonged periods of time represents sustainable use of water. In addition, the majority of the genus can withstand recorded temperatures of 48 degrees Celsius, with no upper limit to be found yet, making this genus a perfect crop for sustainable management of water. The implementation of Permaculture as the underlying agricultural approach, with intercropping and agro-forestry integrated throughout the project, planting a wide variety of Moringa genus trees in different planting patterns as trees and as shrubs will

[15] (NCBA CLUSA International)
[16] (NCBA CLUSA International)
[17] Ibid.

allow for protection of more delicate plants through lessening the amount of sun exposure, providing protection from sand carried by the wind and lessening the rapid water evaporation in the area, leading to a more sustainable approach in water management of the whole irrigation procedure.

The family Moringaceae and its Genus Moringa

The genus Moringa is part of the Moringaceae family of the major group Angiosperms (Flowering plants).[18] There are 13 different species of Moringa trees/shrubs recognised today, although in the literature some 34 different varieties appear listed as Moringa (many are unresolved and considered duplicates of the 13 recognised species). The genus itself is under-researched and under-exploited, with the potential of this genus being huge in terms of medicine, pharmacology, food, animal feed, purifiers, stock, etc. Below is a table of the official genus Moringa:[19]

No	Accepted sci.name	Distribution worldwide	Reference
1.	Moringa arborea	Kenya/a site south-east of Malka Mari	(Species)
2.	Moringa borziana	S-Somalia, E-Kenya	(Moringa genus)
3.	Moringa concanensis	SE-Pakistan (Baluchistan, Sind), India (widespread), W-Bangladesh	(Moringa genus)
4.	Moringa drouhardii	S-Madagascar	(Moringa genus)
5.	Moringa hildebrandtii	+Madagascar (extinct in the wild, but frequently planted)	(Moringa genus)
6.	Moringa longituba	NE-Kenya, SE-Ethiopia, Somalia	(Moringa genus)
7.	Moringa oleifera	**N-India, Nepal, E-Pakistan** (Sind (**i** introduced), Rawalpindi, Pakistani Punjab), Costa Rica (**i**), Australia (**i**) (Queensland (**i**)), trop. Africa (**i**), Java (**i**), Malesia (**i**), Jamaica (**i**), Lesser Antilles (**i**) (St. Martin (**i**), St. Barts (**i**), Antigua (**i**), Saba (**i**), St. Eustatius (**i**), St. Kitts (**i**), Montserrat (**i**), Guadeloupe (**i**), Martinique (**i**), St. Lucia (**i**), St. Vincent (**i**), Grenadines (**i**), Grenada (**i**), Barbados (**i**)), Panama (**i**), Belize (**i**), Aruba (**i**), Bonaire (**i**), Curacao (**i**), Haiti (**i**), Dominican Republic (i), Bahamas (i), Cuba (i), Nicaragua (i), Mexico (i), Venezuela (i), Brazil (c), Seychelles (i), Somalia (i), New Caledonia (i), Fiji (i), Christmas Isl. (Austr. (i)), Palau Isl. (i)	(Moringa genus)

[18] (The Plant List, 2013)
[19] (Tropicos.org)

		(Koror (i), Namoluk (i), Pohnpei (i)), Society Isl. (i) (Tahiti (i), Raiatea (i)), Southern Marianas (i) (Saipan (i), Rota (i), Guam (i)), Niue (i), Mauritius (i), Réunion (i), Rodrigues (i), Madagascar (i), Yemen (i), Oman (i), Cape Verde Isl. (i) (Santo Antao Isl. (i), Sal Isl. (i), Ilha de Maio (i), Ilha de Sao Tiago (i), Fogo Isl. (i)), Ryukyu Isl. (i), Andamans (i), Nicobars (i), Myanmar [Burma] (i), Vietnam (i), Bhutan (i), Sikkim (i), Sri Lanka (i), Laos (i), Philippines (i), USA (i) (Florida (i)), U.S. Virgin Isl. (i)	
8.	Moringa ovalifolia	South Africa (Transvaal (**i**)), Namibia, SW-Angola	(Moringa genus)
9.	Moringa peregrina	Egypt (Eastern Desert, SE-Egypt), Israel (E-Israel: Rift Valley, SC-Israel: Judean Desert, S-Negev Desert), Jordania (S-Jordania), Oman (Dhofar, Mascat & Oman), Saudi Arabia (C-Saudi Arabia, N-Saudi Arabia, NW-Saudi Arabia: Hejaz, SW-Saudi Arabia: Asir), Sinai peninsula (Southern Sinai), Yemen (Aden Desert, coastal Hadhramaut, NE-Yemen: Inner Hadhramaut, SW-Yemen, Tihama), United Arab Emirates, N-Sudan, N-Ethiopia, Eritrea, Somalia, India (**i**)	(Moringa genus)
10.	Moringa pygmaea	NE-Somalia	(Moringa genus)
11.	Moringa rivae	S-Somalia, S-Ethiopia, Kenya	(Moringa genus)
12.	Moringa ruspoliana	Somalia, SE-Ethiopia, NE-Kenya	(Moringa genus)
13.	Moringa stenopetala	SW-Ethiopia, N-Kenya	(Moringa genus)

Figure 79. Moringa: The 13 species and their distributions

The main characteristic of the genus is that it is usually considered in the country of origin as a medicinal tree; for this there is a lot of evidence in ethno-botany and Ayurveda medicine, where it is said that Moringa Oleifera cures 300 illnesses. Aside from its medicinal benefits, today the genus is often used to fight malnutrition by various NGOs across Africa, Asia and South America, mostly for its very high protein, Vitamin A, B, and C, iron and calcium content, where again Moringa Oleifera stands out, partly due to the fact that it has been the most researched and exploited of all Moringa species. Its ground seed powder is used to purify water sources in the developing world, making the water potable and cheap to produce.

It is also used as feed, where it is recorded to be effective in assisting animals in gaining weight and having better production of milk, for propagating other plants, something like spraying a fertiliser made of leaf powder, and the whole genus is being considered in the US as a potential sustainable oilseed feedstock for biodiesel. Its main advantage, according to US researcher K. Shaine Tyson, is that biofuel produced from it is not in direct competition with food, as the plant produces both biofuel feedstock (seeds) and food (leaves) independently, allowing a double harvest and double income.[20]

Moringa seeds contain 30 % to 40 % oil that is high in oleic acid and its biodiesel has better oxidative stability than biodiesel made from most other feed stocks. Leaves and seeds can be harvested from mature trees without damaging them; even though the whole process of harvesting the seeds has not been developed yet, there are a lot of possibilities for new research and development in this area.

Interestingly enough, the genus has naturally spread where it is the most needed in terms of economic and nutritional needs and developmental goals across the developing world.

Genus Moringa in my research

This research will be focusing on Moringa Stenopetala, Moringa Peregrina, and Moringa Oleifera mostly because of their native and naturalised features in relation to Egypt and also because of their high value on the market and the different but complementing characteristics they will bring to the project.

[20] (Schill)

Moringa Peregrina

Figure 80. Moringa Peregrina

Moringa Peregrina is native to Egypt, more precisely to Egypt's Eastern desert and the Sinai, to parts of Israel, Jordan, Oman, Saudi Arabia, Yemen, the United Arab Emirates, Northern Sudan, Northern Ethiopia, Eritrea, and Somalia. It is predominantly native to deserts of all these areas. It is possibly the most unusual and most amazing of all Moringa species in the already unusual Moringaceae family. It is native to the hyper-arid zones, where there is a hyper-arid index of at least 0.03, meaning that there is no or very little rainfall, rarely exceeding 100 millimetres annually. In comparison to other Moringas that could survive with adequate irrigation in hyper-arid zones but prefer more tropical climate, the Moringa Peregrina is quite unique. It is present in arid zones as well. Perhaps because of the climate to which it is native, when Moringa Peregrina seedlings start out, they have broad leaflets and a large tuber. Through many dry seasons, the shoot dies back below ground to the tuber. As the plant gets older, the leaves get longer and longer, but the leaflets get smaller and smaller and more widely spaced. Adult trees produce leaves with a full complement of tiny leaflets, only to drop them as the leaf matures. The pink zygomorphic flowers are sweetly scented and contrast with the blue leaves.[21] Overall, there are very few characteristics it shares with its relatives, with an irregular flower shape, structure of the ovary, and smaller pollen grain being some of them.

In a study done by the Botany Department of the Suez Canal University in Egypt, on propagating the Moringa Peregrina seedlings, they found it hard to replicate successfully the conditions of this wild plant, that is in their view an endangered species in the Sinai due to over-grazing, over-cutting for different uses (for fuel and timber, as its wood is termite resistant), and collecting its seeds for lubrication oil. Due to this, there are not many specimens in the wild to start with and the few seeds that are left wait for the rare few drops of rain to awaken them, and due to climate change the rainfall is becoming less and less each year.

Aside from climate change, perhaps the greatest threat is Bedouin traditions. In a study done by the Botany Department of the Suez Canal University in Egypt, on propagating the Moringa Peregrina seedlings, they found it hard to replicate successfully the conditions of this wild plant, that is in their view an endangered species in the Sinai due to over-grazing, over-cutting for different uses (for fuel and timber, as its wood is termite resistant), and collecting its seeds for lubrication oil. Due to this, there are not many specimens in the wild to start with and the few seeds that are left wait for the

[21] (Olson)

rare few drops of rain to awaken them, and due to climate change the rainfall is becoming less and less each year.

In particular, in South Sinai it is necessary to manage the Bedouins" activities to guard against over-cutting and over-grazing, and increase awareness concerning time and rate of harvest of the plant. Moreover, the Bedouins should be encouraged to develop means of increasing revenue generation from Moringa Peregrina in South Sinai; such as through cultivation of this important plant in its habitats and in botanical gardens. Thus, care efforts should be directed to Moringa Peregrina trees in South Sinai during establishment and growth periods to avoid its extinction. Finally, genetic diversity and heterozygosis of Moringa Peregrina populations in Southern Sinai are in need of further study.

A lot of advertisements for Moringa products will try to tell you that the ancient Romans and Egyptians used Moringa Oleifera, which in fact is not true, as Moringa *Peregrina* oil was one of the many important oils of ancient times and the one more available. There are also a number of different specialities eaten in the southern Arabian Peninsula made out of Moringa Peregrina tuber saplings, which are roasted and eaten.

Moringa Peregrina as a tree native to the desert will serve as a carrier of the forest, the structure, the skeleton of my future vision for the New Green Valley of Egypt. All other vegetation will rely heavily on it and its success to survive on the ground, though there should not be any question about its success as the conditions in the Eastern and Western deserts of Egypt differ in very few ways that cannot be met with sufficient smart and sustainable irrigation system and planning.

Moringa Stenopetala

Moringa Stenopetala, also known as the cabbage tree, is native to Ethiopia and Kenya. It grows best in well-drained soil, and does not grow in waterlogged or swampy soil. It is a fast growing tree, well adapted to semi-arid areas with annual rainfall of as little as 500 mm. It is quite drought tolerant. (146).

There are many different ecotypes and varieties of Moringa Stenopetala, which could be found in Ethiopia and across Africa. However, today it is nearly extinct in Ethiopian wilderness, but is widely planted as an important indigenous vegetable and as a crop plant (146). It was planted by agriculturalists on the complex system of terraces built high up in the Ethiopian Highlands in order to retain water and enrich the soil, where it became domesticated and was bred to improve productivity, the taste of their leaves, and the size of their seeds. Since then, the improved trees have been introduced into other areas such as the Rift Valley, where it becomes very popular as a staple food and feed for animals, especially because its leaves are available in the dry season when there are not many other vegetables available. Moringa Stenopetala is an evergreen perennial plant that can last up to 60-100 years without reduction in productivity.[22] The second most studied of all Moringas, it has wide application possibilities.

Moringa Stenopetala has proven to be more effective than Moringa Oleifera in purifying water from heavy metals, especially lead, which is highly present in many African springs, such as in those of Malawi.[23] A mature tree of Moringa Stenopetala 4-13 years old can produce 2.3-5 kg of seeds, which contain great amounts of oil, some 5.1 ± 0.27 g/100 g and 96 ± 10.5 g/kg DM, with dietary fibres of 5.1 ± 0.27 g/100 g and 96 ± 10.5

[22] (FAO)
[23] (L. M. Mataka BEd., 2006)

g/kg DM.[24] which can be used as highly nutritious cooking oil. After the oil extraction the ground Moringa Stenopetala seed powder can be used as water purifier. Amongst its many uses is the use of its roots, as the roots of Moringa Stenopetala chopped and mixed with water are used to successfully treat severe cases of malaria.[25]

One of its many important uses for employing it in my project of making the New Valley in Egypt is its already proven use in shading capsicum and sorghum crops, as a companion plant, for which it will come in very handy in the Saharan sun.

There are numerous other medicinal, agricultural and food uses for this amazing native African tree. Perhaps one of the uses that make it so desirable for my project is that Moringa Stenopetala is native to Africa, meaning little or no effort concerning education of farmers will be needed. Its integration into local cuisine is also a positive factor and quite the contrary to Moringa Oleifera.

Moringa Oleifera

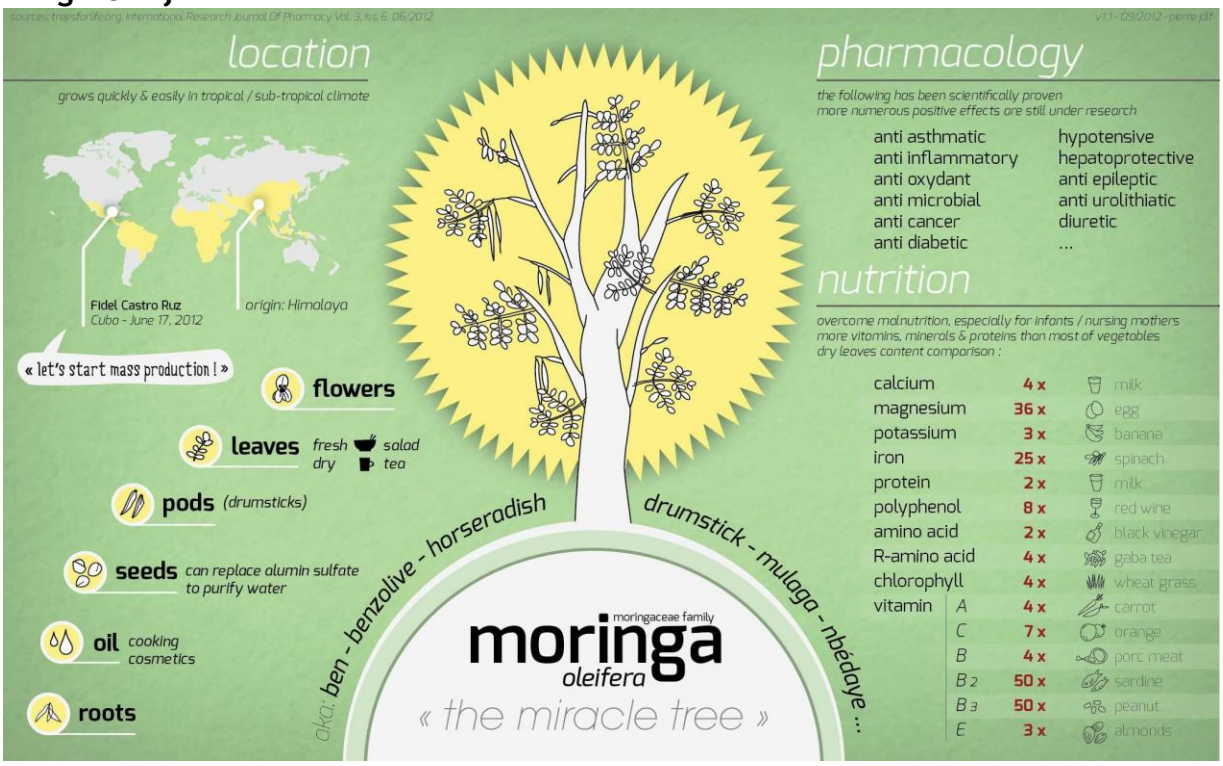

Figure 81. Picture from www.treesforlife.org International Research Journal of Pharmacy Vol. 3Iss 6.6.2012

Definitely the most well-known of all Moringa species is the Moringa Oleifera, which is hailed by the Food and Agriculture Organisation of United Nations as the tree of the 21st century to combat malnutrition and undernourishment and praised as a solution to world hunger. All around the world Moringa Oleifera is the subject of legends and praise, awe and respect, so much so that it has been called "Miracle Tree", "Mother's Best Friend", and "Never Die".[26]

Moringa Oleifera can be grown as a shrub or as a tree, depending on the planting spaces between the seedlings, and can also be planted for different purposes in different types

[24] (146)
[25] (FAO)
[26] (Carrie Rubicon Health Organisation)

of schemes. It is quite a multi-purpose plant, with its leaves, roots and immature pods being consumed as a vegetable. All parts of the Moringa tree – the bark, pods, leaves, nuts, seeds, tubers, roots, and flowers – are edible.[27] The leaves are used fresh or dried and ground into a powder; in Vienna 100 grams of this powder costs around 10 Euros. This explains how lucrative this plant is, how great the demand for it is not just in the developing world as a substitute for fresh fruits and vegetables but also in the developed world, where it is perceived as an elixir super-food plant, especially popular amongst vegans and vegetarians. The seed pods are picked while still green and eaten fresh or cooked. If left to ripen the seeds can be collected for oil. Moringa Oleifera seed oil is sweet, non-sticking, non-drying and resists rancidity. In the process of making the oil, seeds are ground to extract the extra virgin oil, while the leftover seeds can still have a spectacular application: they can be used to purify drinking water that becomes of greater quality than commercial water. This is currently being studied at the University of Lausanne in Switzerland and many different universities in Africa. The seeds can also be eaten while green, roasted, powdered, steeped for tea, or used in curries.

Some of the world's leading NGOs in stopping world hunger, like NCBA CLUSA have done a commendable job in educating people, most importantly women, on how to integrate Moringa into their diet, how to prepare different dishes out of it, which is one of the most important steps in eradicating world hunger - teaching people how to use what they have in the best possible ways. Gram per gram Moringa has nutritional value matched by, perhaps, no other, with some 25 times the iron of spinach, 4 times the Vitamin A of carrots, and 36 times the magnesium of eggs being just some of the surprising figures of Moringa Oleifera leaves.[28]

NCBA CLUSA has set a commendable example of how NGO projects should be run in Africa. They have passed the sustainability test, one of which is that their projects should be structured to continue long after they are gone: they have educated the people well, taught them how to start nurseries for Moringa plants, how to nurture them, how to harvest them. This has resulted in record harvests of every second week and on the 45th day after the seedling has sprouted, and all this at the edge of the desert on the very border between the Sahara and the Sahel in Niger.

Confirmations from projects such as this and similar ones in the region is what gives this research strength and reassurance that nothing is impossible, that our only borders are in our own minds and our dreams, because if all your dreams have come true you must not be dreaming big enough.

The use of Moringa Oleifera in my project will play a great role, not just as it is needed to help establish the first soil in my Permacultural forest crop garden valley, but because it will also bring the farmers a much needed income to help them start their own households, thus lowering the current inequality between the cities and villages, and especially between the Nile Valley and the rest of the country.

Conclusion

Using nature as a guide has never turned out to be a bad idea. By trying to replicate the conditions in the New Valley made by the Nile in the Nile Valley with pipelines, we will be able to develop fertile soil more quickly and in a more controlled way, with

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[27] (FAO).

[28] (NCBA CLUSA International)

guaranteed success as we will be using native species as the backbone of the project. By using the Moringa family and especially Moringa Peregrina, Moringa Stenopetala, and Moringa Oleifera we will be able to provide for adequate nourishment of new species in the area. The initial conqueror will be the hyper arid native species of Egypt, the Moringa Peregrina, which will help not just to start a New Valley but to preserve biodiversity as it is a much endangered species, but yet quite a lucrative one too. Moringa Peregrina will be followed by Moringa Stenopetala and Moringa Oleifera, two complementing species with similar requirements, both with extreme growth and production, and both having been tested in similar conditions, although with Moringa Oleifera (because of widespread appearance and distribution) being more often recorded.

The closest examples are located in Niger and Morocco, and in both cases the introduction of Moringa Oleifera into the desert was extremely successful. This tree is recorded to have extreme drought tolerance and to be able to withstand extreme temperatures with no recorded upper limit, and the current one standing at 48°C. This base forest-crop, trees that can be harvested for multiple purposes, will provide a base growing ground for other more sensitive plants to be established. Firstly, the implementation of all the lucrative oasis plants including palms, dates and figs as another layer of canopy in our Permaculture forest will be included. This will be followed by the integration of salinity resistant plants such as *Limonium family* after which a more sensitive but yet still quite desirable plants could be introduced, all within a scheme of 7 layers in a vertical forest cut and desirable numbers of rows in different agroforestry schemes. This factored with the observed scientific phenomena of plant positive association in arid environments will provide for a fast development of an independent ecosystem. That will ultimately produce fertile soil and help preserve and develop a new ecosystem close to those which currently exist in Egypt's oases.

This will lead to a day in a hundred years" time when the whole system will be independent and self-reliant, capable of self-management, and able to self-sustain itself. Making a path for the switch, the much needed switch from the Sahara to the Sahel, one that with careful planning we hope to trigger allowing for unimaginable exploitation of the Sahara Desert in agronomical terms, providing the future generations not just with the same conditions as we had, which leads to sustainability, but with far greater ones which allow for undisturbed development in harmony with nature.

Description of the patented methodology that came out of this PhD research, with the original patent claims in German and English, description and drawings being attached as ANEX I

Verfahren und Anlage zur Bereitstellung von Wachstumsflächen

Die Erfindung betrifft ein Verfahren zur Bereitstellung von land- und forstwirtschaftlich verwendbaren Wachstumsflächen in hyperariden, ariden und semiariden Wüsten, wobei auf den Wachstumsflächen ein Wachstumssubstrat aufgebracht wird. Ferner betrifft die Erfindung eine Anlage zur Durchführung des erfindungsgemäßen Verfahrens.

Im Stand der Technik liegen in der Bewässerung, Düngung und Bepflanzung von Flächen, welche trockenen und heißen klimatischen Bedingungen ausgesetzt sind zahlreiche Schwierigkeiten.

Es sind im Stand der Technik zahlreiche Verfahren zur Versorgung von landwirtschaftlich genutzten Flächen mit Wasser und Nährstoffen bekannt. Da Gewässersedimente einen hohen Nährstoffgehalt haben, werden diese oft zur Nährstoffversorgung verwendet.

Die CN 104855211 A beschreibt die Pflanzung von Teebaumkulturen in eine Mischung aus Erde und Flussschlamm. Die CN 105210752 A offenbart die Kultivierung von Maulbeerbäumen in eine Mischung aus Humus, Löss und Flusssand. Die CN 1305691 A beschreibt ein Verfahren zur Bepflanzung von Wüstengebieten, wobei kommunales Abwasser zur Nährstoffversorgung verwendet wird.

Die CN 105706728 A offenbart eine Vorrichtung zur unterirdischen Tropfbewässerung. Die DE 8033352 U1 beschreibt einen Schwimmbagger und die DE 1130375 B zeigt einen Saugbagger.

Es ist eine Aufgabe der Erfindung, die Nachteile des Standes der Technik zu überwinden und ein Verfahren der Systementwicklung einer nachhaltigen Bewaldung in hypertrockenen, trockenen und halbtrockenen Wüsten weltweit bereitzustellen.

Die Erfindung betrifft ein Verfahren zur Bereitstellung von land- und forstwirtschaftlich verwendbaren Wachstumsflächen in hyperariden, ariden und semiariden Wüsten, wobei auf den Wachstumsflächen ein Wachstumssubstrat aufgebracht wird, wobei das Wachstumssubstrat Sedimentablagerungen aus Gewässern, wie Seen oder Flüssen, enthält oder daraus besteht, und wobei die Sedimentablagerungen und der pumpfähige Schlamm in abgedeckten Kanälen oder Röhren transportiert wird.

Erfindungsgemäß ist vorgesehen, dass die Sedimentablagerungen aus dem Gewässer abgebaut, gemahlen oder zerkleinert, eventuell gesiebt und in einer Verarbeitungsanlage, mit Wasser zu einem pumpfähigen Schlamm vermischt und der Schlamm auf die Flächen aufgetragen wird.

Ferner betrifft die Erfindung eine Anlage zur Bereitstellung von land- und forstwirtschaftlich verwendbaren Wachstumsflächen in hyperariden, ariden und semiariden Wüsten, wobei erfindungsgemäß vorgesehen ist, dass die Anlage eine Sedimentabbauvorrichtung, ein erstes Transportmittel, eine Verarbeitungsanlage und ein zweites Transportmittel umfasst, wodurch das abgebaute Sediment als Wachstumssubstrat auf Wachstumsfläche aufgebracht werden kann.

Erfindungsgemäß kann das Verfahren die folgenden Schritte umfassen:

a) Auffinden des entsprechendes Sees in der Wüste,

b) Lokalisieren der Ablagerungen in diesem See,

c) Festlegen der Ausgrabungstechnik, vorteilhafterweise Baggern,

d) Bau der Transporteinrichtungen für die ausgegrabenen Sedimente bis zu einer Verarbeitungsanlage,
e) Bau der Verarbeitungsanlage und Messen des Tongehalts in den ausgegrabenen Ablagerungen,
f) Einstellen der geeigneten Mischung von Sediment und Wasser,
g) Bau der Hauptrohrleitung und Pumpen dieser Mischung in die für den Transport der Sediment-Wasser-Mischung vorgesehenen Hauptrohrleitung mit minimalen Verdunstungsverlusten,
h) Bau von sekundären und tertiären Rohrleitungen und Verteilung der Sediment- Wasser-Mischung durch die sekundären und tertiären Rohrleitungen bis zu ausgewählten Feldern,
j) Errichten des entsprechenden Schutzes vor Wind auf den Feldern,

k) Pflanzen von ersten Stecklingen,

l) Bilden von Clustern von Landwirten und Information dieser über den Nutzen von nichthölzernen Produkten und Agroforstwirtschaft im Allgemeinen und
m) Entwickeln von erhaltbaren Lebensräumen des 21. Jahrhunderts um den Wald zu pflanzen und das Wachstum von Wald und Erdboden zu verfolgen.

Eine weitere Aufgabe der Erfindung besteht in der Bereitstellung einer Anlage zur Durchführung des erfindungsgemäßen Verfahrens umfassend eine Sedimentabbauvorrichtung, ein erstes Transportmittel, eine Verarbeitungsanlage und ein zweites Transportmittel.

Gegebenenfalls beginnt das Verfahren mit der Lokalisierung der Sedimentablagerungen in Seen, der Bestimmung von Tiefe und den verschiedenen Härtestufen der Sedimente. Danach kann die Entscheidung über das entsprechende Schiff für das Ausgraben dieser Ablagerungen gefasst werden. Abhängig von der Entfernung bis zum entsprechenden Ufer werden schwimmende Rohrleitungen oder Schiffe ohne Antrieb für das Ausgraben verwendet. Weitere Berechnungen werden ausgeführt um die Transportmethode, welche benutzt wird festzulegen. Dabei werden die Verdunstungsrate auf den Schiffen und die Entfernung, welche zurückzulegen ist, berücksichtigt.

Das ausgegrabene Sediment wird mit Landrohrleitungen zur Verarbeitungsanlage weitertransportiert. In diesem Objekt durchlaufen die Sedimente den Prozess des zusätzlichen Brechens, Mahlens und Mischens zu einer homogenen Sediment-Wasser-Mischung im Verhältnis 40 (20): 60 (80) Sediment zu Wasser (Gewichtsverhältnisse).

Das Mischverhältnis hängt vom Tonanteil im Sediment ab, welcher durch Benutzung von drei Verschiedenen Sensorarten bestimmt wird, alles mit dem Ziel das Bilden von nicht-newtonschen Flüssigkeiten zu verhindern, welche üblich sind, wenn Ton in großen Anteilen vorhanden ist. Nachdem das Verhältnis Sediment-Wasser in der Mischung eingestellt ist, wird die Mischung in die Landrohrleitung gepumpt.

Der Standort der Rohrleitung wird so ausgesucht, dass er den besten Weg im Verhältnis zum Gesamtausstoß von CO2 bildet. Das heißt, eine schon zur Verfügung stehende Infrastruktur soll benutzt werden, in Ägypten im Fall des Nasser-Sees soll der Scheich Zayed-Kanal benutzt werden. In anderen Fällen soll der freie Fall so viel wie möglich intergiert werden. Die Ausbringung der Mischung in hypertrockenen Wüsten soll im besten Fall mittels unterirdischer Tropfenbewässerung durchgeführt werden.
Wenn nicht, dann mit dem Tropfsystem, welches mit Mulch so schnell wie möglich abgedeckt werden soll um unnötige Wasserverdunstung zu verhindern.

Um das Bewaldungsprojekt in hypertrockenen Wüsten erfolgreich umzusetzen, verlangt dieses den Zugang zur Baumpflanzung, die nicht Monokulturen oder Plantagen sind und es werden zwei bis drei Folgearten gepflanzt. Der gepflanzte Wald soll mindestens drei lokale und heimische Baumarten beinhalten, verbunden mit einer Mischung aus anderen Frucht tragenden und ertragsreichen Baumarten, welche für Wüstenbedingungen geeignet sind, gepflanzt in einer Mischung von Bäumen und Büschen aus der Familie der Hülsenfrüchtler. Das System sollte wie ein natürlich vorkommender Wald aussehen. Bedeutung sollte der Pflanzung von Schutzunterholz und –buschwerk am Rand unseres Systems gegeben werden, und zwar zusammen mit einheimischen Arten, um Schutz vor Sandstürmen zu haben. Oder man sollte die Benutzung von Roboterteleskopständern für Solarpaneele, welche als Schild verlängert werden können, erörtern. Ein sehr wichtiger Teil der Entwicklung des Waldes und des Erdbodens in hypertrockenen Wüsten ist das Näherbringen der örtlichen Bevölkerung. Die örtliche Bevölkerung soll vom ersten Tag an in den Planungsprozess einbezogen sein. Noch wichtiger, eine Akademie für die Dauer von fünf Jahren soll von Seiten der Projektinvestoren zur Verfügung gestellt werden, zusammen mit der Bildung eines Clusters von Landwirten für Landwirte, die lernen werden wie sie den Wald entwickeln sollen. Das hat grundlegende Bedeutung, denn solche Systeme sind wissensintensiv, aber nicht arbeitsintensiv. Diese Akademie soll über die Bedeutung der nichthölzernen

Produkte, über die Entwicklung des Erdbodens informieren sowie wie Stecklinge und Ableger aus den verfügbaren Mitteln zu bilden sind, wie man den fruchtbaren Waldboden bewahren kann, wie die unterirdische Bewässerung zu steuern ist, welche Pflanzen zu einander gut passen und wie die lebende Welt eines Waldes im Erdboden und über ihm zu verwalten und zu beaufsichtigen ist.

Das für diese Bewaldung benutzte System ist in der Lage einen außerordentlich nachhaltigen Wald in hypertrockenen Wüsten zu bilden und, im Vergleich mit der konventionellen Wüstenlandwirtschaft, wird von Beginn an bis zu 50% weniger Bewässerung nötig sein. Im Verhältnis zu der konventionalen Landwirtschaft wird bis zu 80% weniger Bewässerung benötigt sein, wenn das System einmal vollkommen etabliert ist und abhängig von den gepflanzten Arten.

Gegebenenfalls umfasst die Erfindung ein Verfahren für eine erfolgreiche Bewaldung

von halbtrockenen, trockenen und hypertrockenen Wüsten, die im Grunde aus der Benutzung eines Baggersystems, der Transport-Pipelines und der Agroforstwirtschaft besteht, gefolgt von der intensiven Bildung der örtlichen Bevölkerung über Agroforstwirtschaft mit Ziel einer erfolgreichen Projektumsetzung.

Gegebenenfalls umfasst das erfindungsgemäße Verfahren die folgenden Schritte:

Das System beginnt durch die genaue Lokalisierung der abgelagerten Alluvialsedimente im See, und der Bestimmung der Sedimentfestigkeit und –tiefe (und im Fall eines neu geplanten Sees, dem zweckmässig designten Stauwehr mit allen notwendigen Berechnungen um den genauen Standort der Sedimentflussbildung zu bestätigen mit mindestens vier Jahren Beobachtung der Sedimente (im Rahmen) des zukünftigen mit dem Damm verbauten Flusses, um die günstigste Stelle für den Damm bestimmen zu können, der den Sedimentfluss zum Ufer bringen soll, wo sich die Verarbeitungsanlage befinden wird.

Der zweite Schritt ist das vertikale Ausgraben dieser Sedimente mit Baggerschiffen/- booten, welche mit Sonnen- und Windenergie angetrieben werden, abhängig von der Steife und den Konsistenz der ausgegrabenen Sedimente (und im Fall eines neu geplanten Sees, wird sich das fixierte Rohr mit der Pumpe an einer Stelle befinden, an welcher der Damm nah genug zu der Verarbeitungsanlage ist, abhängig von der geographischen Position, aber immer weniger als fünfzig Meter; der dritte Schritt ist der Anfang des Horizontaltransport vom Baggerschiff/-boot bis zu der Verarbeitungsanlage (im Fall eines neu geplanten Sees wird das ein Transport vom Damm zu der Verarbeitungsanlage im Winkel des Ufers sein, wo wir drei verschiedene Transportmethoden haben: mittels eines Schiffes ohne eigenen Antrieb, das das Baggerschiff begleitet, dem Baggerschiff selbst und einer schwimmenden Rohrleitung, wobei die Verdunstungsrate auf dem Schiff ohne eigenen Antrieb und die Entfernung, die es zurücklegen muss, berücksichtigt werden muss, weshalb die Effizienz eine Schlüsselrolle in der Beschlussfassung spielt.

In allen Fällen werden die Ablagerungen der Sedimente in die Hauptverarbeitungsanlage ankommen, wo sie mit dem Ziel der Herstellung einer homogenen Masse gemahlen und vermischt werden und danach mit verschiedenen Sensoren gescannt werden um das Vorkommen von Tonerde in den Sedimenten einschätzen zu können, da Tonerde der Hauptfaktor in der Entwicklung von nicht-newtonschen Flüssigkeiten in den turbulenten Rohrleitungsflüssen ist (das Vorkommen von anderen Partikeln wird auch bestimmt), und danach werden die Sedimente im einem Verhältnis 40 (20): 60 (80) Sediment zu Wasser gemischt, abhängig von der Menge an vorhandenem Ton; es ist sehr wichtig darauf hinzuweisen, dass dieser Transport in hermetisch geschlossenen Containern und Rohrleitungen ausgeführt wird, um die Möglichkeit eines übermässigen Flüssigkeitsverlustes aufgrund des hohen Verdunstungsgrads in Wüsten zu verringern; von hier wird es in die speziell angefertigten Rohleitung gepumpt, die sich ihren Weg durch die Wüste bahnt.

Für den Standort der Rohrleitungen versuchen wir die schon vorhandene Infrastruktur zu benutzen, besonders bei kleinen Staudämmen, da der Sedimentfluss in solchen Fällen immer nah an dem Damm selbst ist und das gesamte beschriebene System wird sich in unmittelbaren Nähe des Dammes befinden, sodass die Landrohrleitungen

(hergestellt aus Polyethylen von hoher Dichte (HDPE) welches einem Druck bis zu 1.1 MPa standhält) der bestehenden Infrastruktur, welche vorerst für die Errichtung des Dammes benutzt wurde, folgend in besonderen Fällen, wie beim See des Assuan-Staudammes, wo der See sehr lang und die Entfernung des Sedimentflusses bis zum Damm sehr weit ist, benutzen wir die zur Verfügung stehende Infrastruktur, in diesem konkreten Fall den Scheich-Zayed-Kanal, als Weg in den die Landrohrleitungen gelegt werden, aber der Kanal ist hier wasserdicht um Leckagen zu verhindern, sodass die Trägerkonstruktion von oben kommen muss und den Kanal ähnlich einem Dach aus Solarpaneelen schließen wird, der gleichzeitig die enorme und die in Äquatornähe typische Verdunstungsrate verhindern wird, aber wir berücksichtigen auch die Geographie der Region und die Wüstengeologie – welche Art von Wüste, Sand, Gestein oder eine Mischung – unter Berücksichtigung des Bestehens von verfügbaren nahen Oasen und wir versuchen diese Oasen zu verbinden, denn dadurch ist das Bestehen vom Grundwasser gesichert, wenn man den Weg auswählt und die Hauptrohrleitung errichtet, dann folgt die Aufteilung der Hauptrohrleitung in kleinere Rohrleitungen, welche zu einzelnen Bereichen führen.

Die Herangehensweise für die Endrohrleitungen hängt vom Gebiet und davon ab ob sich die Felder auf einem Bergfelsen mit fester Oberfläche auf Sand-Stein-Bergflächen oder auf einer ebenen Sand- oder Steinfläche befinden, denn jede von ihnen wird einen anderen Zugang für die Bewahrung der Sedimente, angefangen mit einer Bewässerungsterrasse bis zu Tropfbewässerung mit Sedimenten , wenn die Bewässerungsmethode bestimmt ist und man mit der Bewässerung des Feldes begonnen hat, wird eine besondere Mischung von autochthonen Wüsten-, einfachen Wüsten-, Halbwüsten- und Mittelmeerpflanzen im Agroforstwirtschaftssystem gepflanzt um das Stickstoffniveau mit der ersten Bepflanzung zu fixieren.

Die tragende Pflanzenkultur oder Baumart, welche benutzt wird, muss eine lokale Baumart oder aus der Moringa-Familie sein (im Fall der ägyptischen Sahara ist es die Moringa Peregrina) welche den Stickstoff fixiert, und ein solches System wird uns ermöglichen den sehr wertvollen Boden zu bewahren, die Wälder zu entwickeln und zu vermehren, welche – neben dem Speichern von Kohlendioxid– auch die örtliche Bevölkerung ernähren und mehr Erde entwickeln können, wodurch ein solches Projekt zum Beispiel einer nachhaltigen Erstbewaldung/Aufforstung in hypertrockenen Wüsten wird.

Durch die Verwendung von agroforstwirtschaftlicher Erstbewaldung/Aufforstung in hyper-ariden Wüsten werden wir die Möglichkeit haben, neue Erde „wachsen“ zu lassen, wodurch es eine mehr als nur nachhaltiger Methode ist, die erste Bewässerung mit unserer Mischung wird neue Erde schaffen und dem Boden die für die Entwicklung von Agroforstwirtschaft notwendigen Nährstoffe liefern, und mit einer Sorgfältigen Pflege und Instandhaltung und einem geplanten Wachstum, der mittels intensiver Schulung der Bevölkerung verwaltet mittels einer der örtlichen Bevölkerung, die diese Felder bewirtschaften wird und mittels eines praktisch mitarbeitenden Zugangs von mindestens fünf Jahren (was auch den Beobachtungszeitraum von sechzig Jahren der Kohlendioxid-Zertifikate und gemäß der Bewaldungsdefintion der Vereinten Nationen ermöglichen wird, wird das Projekt in der Lage sein den Wald zu verlassen, in der er ohne menschliche Hilfe, weder mit Bewässerung noch auf eine andere Weise, weiterwächst), dieser Zugang kann einen großen Einfluss auf das globale Klima haben, nicht nur durch Stützung auf die Bewaldung, sondern auch durch die Anwendung des systemischen Ansatzes, durch welchen Seen gereinigt werden um den Bewaldungsprozess zu beschleunigen und auf diese Weise auch auf das Mikroklima an

richtiger Stelle zu wirken und in der entsprechenden Zeitdauer eine Veränderung des globalen Klimas einzuleiten, wenn das Projekt groß genug ist.

Die Vorteile dieses Prozesses werden weitläufig sein, denn mit ihm werden nicht nur Wassereinsparungen erzielt und eine weitere Bewässerungslösung unter Benutzung des ausgegrabenen Materials geschaffen, sondern auch eine neue nachhaltige Weise wie man wieder Land von den Weltwüsten erschließen kann.

Gegebenenfalls umfasst das erfindungsgemäße Verfahren, dass durch die Lokalisation und Analyse des genauen Ortes, wo sich die Alluvialablagerungen am Boden des Sees befinden, der Bestimmung der Tiefe, Zusammensetzung und der verschiedenen Niveaus, der Härte der Sedimente (und im Fall eines neu geplanten Sees, dem zweckmäßig designten Stauwehr mit allen notwendigen Berechnungen um den genauen Standort der Sedimentflussbildung zu bestätigen mit mindestens vier Jahren Beobachtung der Sedimente (im Rahmen) des zukünftigen mit dem Damm verbauten Fluss, um die günstigste Stelle für den Damm bestimmen zu können, der den Sedimentfluss zum Ufer bringen soll, wo sich die Verarbeitungsanlage befinden wird) –hier ist es wichtig eine langfristige Prognose über den Standort und den Weg, welchen in Zukunft der Sedimentfluss nehmen wird, während er langsam zum Staudamm fließt, zu erstellen und die günstigste Stelle für das Ausbaggern des alluvialen Ablagerungsschlammes mit der feinsten Granulierung, reich an Nährstoffen sowie des Standortes, welches eine gute Auswahl für die Ausgrabung auf einen längeren Zeitraum sein wird, zu identifizieren.

Gegebenenfalls ist erfindungsgemäß vorgesehen, dass das Ausbaggern der Ablagerungen und ihr Transport bis zu der Hauptverarbeitungsanlage, wie bereits erklärt, im zweiten Schritt, das Vertikale Ausbaggern dieser Ablagerungen mit Baggerschiffen/-booten, welche mit Solar- und/oder Windenergie angetrieben werden bei dem die Extraktion hauptsächlich von der Steifheit und der Konsistenz der ausgegrabenen Ablagerungen abhängen wird und weiter im dritten Schritt, der Beginn des horizontalen Transports vom Baggerschiff bis zu der Verarbeitungsanlage, aus drei verschiedenen Transportmethoden besteht: mittels eines Schiffes ohne eigenen Antrieb, das das Baggerschiff begleitet, mit dem selbst Bagger und einer schwimmenden Rohrleitung, wobei auch die Verdunstungsraten auf dem Schiff ohne eigenen Antrieb und die Entfernung berücksichtigt werden muss, weshalb die Effizienz eine Schlüsselrolle in der Entscheidungsfindung spielt.

Unter Berücksichtigung, dass die erwartete Granulierung (Zusammensetzung des ausgegrabenen Materials) feine Partikel von 0,2 Millimeter – 0,002 Millimeter im Durchmesser haben soll, wurde festgestellt, dass die Ausgrabungsaktivitäten mittels Saugbagger mit Fräsköpfen (Schneidkopfsaugbagger – Cutter-Suction dredgers) durchzuführen sind. Diese Baggerart besitzt einen Schlauch, der eine Tiefe von 30-35 Metern erreichen und – wenn notwendig – sich mittels eines Fräsmechanismus am Mundstück durch Ablagerungen schneiden kann, was ihn zu einer vernünftigen Option macht (und zu einer Option, die mit einer anderen ausgetauscht werden kann, abhängig von Standort sowie Granulierung und Zusammensetzung der Ablagerungen).

Zuerst erfolgt erfindungsgemäß das Fräsen und Mahlen der größeren Partikel am Eingang des Saugrohrs des Baggers, wo alle Stücke des Materials oder der Vegetation, wie Äste, Blätter und andere organische Materien, aufgesaugt und gemahlen werden,

was den Transport mehr oder weniger homogenen Sediments ermöglicht. Statt der Nutzung von traditionellen Fossiltreibstoffen für den Antrieb dieses Systems der Baggerschiffe, schlage ich die Nutzung einer Schiff-Kombination, angetrieben mit Solar- und Windenergie vor. Die Kombination von Wind und Sonne für maximale Effizienz wird uns die Nutzung der geographischen Lage der Wüsten und der Änderung der Wetterumstände zwischen Tag und Nacht ermöglichen und den gesamten Ausstoß von Treibhausgasen vermindern.

Die für den Antrieb von solchen Schiffen benötigten Solarpaneele können als schwimmendes Schiff ohne Antrieb installiert werden, das zusammen mit dem Schiff gezogen werden kann und im Fall, dass ausreichende Ablagerungen die Benutzung von Schiffen rechtfertigen, können die Solarpaneele als Vordach für die Mannschaft über der oberen Schiffsfläche aufgebaut werden. Der Windenergiegenerator kann auf die gleiche Achse wie der Schlauch gestellt werden, was dem Ausgrabungsschiff zusätzliche Stabilität verleiht, in dem Fall, dass ein Schiff benutzt wird, können abhängig von der Länge des Schiffes mehrere Windenergiegeneratoren angebracht werden.
Wenn das Schiff aber zwei oder mehrere Rotoren / Windgenerator besitzt, könnte einer direkt mit der Baggerschlauchpumpe verbunden werden, damit keine Energie während der Umwandlung in Strom und dann wieder bei der Umwandlung in mechanische Energie verloren geht.

Diese Schiffsart wird im Fall großer Seen, wie beim Stausee des Assuan-Staudamms, große Schlammmengen in die schwimmende Rohrleitung oder ins Lager bringen. Wenn notwendig, können in den Seen auch Abbau in kleinerem Umfang, oder ein hoher Schwimmbagger (High Lift Dredge) mit Booster-Pumpe angewendet werden, welche mit zusätzlichen schwimmenden Solarpaneelen oder einem eingebauten Windgenerator angetrieben werden. Da das Ausgraben, Baggern und der Transport in Wüsten stattfinden wird, ist die Effektivität solcher Wind- und Solarschiffe zweifellos groß. Die Sonne ist in der Wüste am mächtigsten und mit Wasser, um die Solarpaneele abzukühlen, wird ihre Effektivität zusätzlich wachsen, zusätzlich unterstützt mit den ständigen Winden, welche üblicherweise während der täglichen Temperaturveränderungen auftreten.

Durch die Benutzung einer solchen Transportweise würden wir eine nachhaltigere Lösung ohne die Benutzung von Fossiltreibstoffen schaffen.

Gegebenenfalls kann weiters vorgesehen sein, dass die Ausgrabungen der Ablagerungen am Boden des Sees und ihr Transport zu der Hauptverarbeitungsanlage im Fall eines neu geplanten/neu geschaffenen künstlichen Sees der Wehr- oder Staudamm so zu konzipieren ist, dass er den Verlauf des zukünftigen Sedimentflusses zu einem fixierten Rohr, welches am Seeufer liegt und das mit der Hauptverarbeitungsanlage direkt verbunden ist und eine Pumpe an der Berührungsstelle des Dammufers und des Rohrs besitzt,

richtet.

Diese Pumpe wird wie ein Saugbagger funktionieren und nah genug zu der Verarbeitungsanlage sein. Abhängig von der örtlichen Standortgeographie ist sie immer weniger als 50 Meter von der Verarbeitungsanlage entfernt, wie im Fall eines neu geplanten Sees. Das wird ein einziger Transport vom Damm zur Verarbeitungsanlage sein, in einem Winkel zur Küstenlinie da das Rohr dort verlegt wird. Deshalb ist es notwendig bei neu geplanten Seen den genauen Standort des Sedimentflusses präzise zu berechnen, was mindestens vier Jahre Beobachtung der Sedimente und des Flusses, welcher mit einem Damm verbaut werden wird, fordert, um die geeignetste Stelle des Wehrdammes zu bestimmen. Das wird auch vom geographischen Standort abhängen und der Hauptfaktor, welcher bei der Entscheidung über den Standort des Dammes berücksichtigt werden muss, ist, dass der Damm nicht höher als zwei bis fünf Meter ist, nachdem dieses der erste See sein wird, welchen man am Fluss bilden wird, und die Stauung vor dem Hauptdamm stehen muss mit der einzigen Ziel den Sedimentfluss zum Ufer zu leiten, wo das Saugrohr geplant wird und wo es mit der Verarbeitungsanlage verbunden wird.

Es ist also besser diese Dämme nicht über den ganzen See zu planen um den Fluss nicht gänzlich zu sperren, sondern - dort wo es möglich ist - den Sedimentfluss mit zwei oder drei kürzeren, kleineren aufeinanderfolgenden Dämmen zu versperren.

Gegebenenfalls kann vorgesehen sein, dass die Verarbeitung der ausgegrabenen alluvialen Schlammablagerungen, welche extrahiert und bis zu der Hauptverarbeitungsanlage auf verschiedene Weisen transportiert werden, zuerst aus der Lagerung des Materials in hermetisch geschlossenen Räumen mit Tankbehältern bestehen wird. Hier werden die Sedimente gebrochen, gemahlen und mittels mechanischer Kraft der Schneider und Brecher gemischt (mit dem Ziel eine homogene Mischung aus Wasser und Sedimenten mit Partikeln in der Spannweite von 0,2 Millimeter – 0,002 Millimeter zu gewinnen). Dann erfolgt der Transport dieses Materials in speziellen geschlossenen Kammern mit einer Rotationsplattform zur Ablagerung.

Gegebenenfalls ist vorgesehen, dass die ausgegrabenen alluvialen Schlammablagerungen in der Rotationskammer bearbeitet werden, und dass in dieser Kammer die Ablagerungsgeschwindigkeit mit optischen Sensoren gemessen wird, was uns ermöglicht die Zusammensetzung der Hauptpartikel in der Mischung zu definieren. Nach der Ablagerung werden zusätzliche Sensoruntersuchungen vorgenommen um die genaue Menge von Tonerde und anderen Partikeln in der ausgegrabenen Mischung zu berechnen. Ton ist der Hauptfaktor in der Entwicklung von nicht-newtonschen Flüssigkeiten in turbulenten Rohrleitungsflüssen.

Die Sedimente werden dann im Verhältnis von 40:60 Sedimente und Wasser

gemischt, mit einem befriedigenden Niveau an Tonerde von 25% der gesamten Trockenmaterie oder bis zu 20:80, abhängig vom Tonanteil in der Mischung. Der wichtigste Teil in diesem Schritt ist das Kontrollieren der Bildung der nicht-newtonschen Flüssigkeit.
Wenn dieses nicht sorgfältig beobachtet wird, könnte es wegen den extremen Wetterbedingungen der Wüste zu einer Explosion in den Rohrleitungen kommen. Diese spezifischen Verhältnisse 40 (20):60 (80) sind deshalb der Schlüssel für das Funktionieren des Systems.

Gegebenenfalls umfasst die Erfindung, dass in der Endanlage der ausgegrabene Alluvial-Schlamm den endgültigen Mahl- und Mischungsprozess durchlaufen wird, wo aufgrund der Berechnung aus dem vorhergehenden Schritt und im Verhältnis zum Tonanteil – wenn notwendig – der Wasseranteil erhöht oder verringert wird. Von hier aus werden die Sedimente in Rohrleitungen gepumpt und bis zum ausgesuchten Standort transportiert. Abhängig vom Standort der nächsten Rohrleitung und der für das Einpumpen der Mischung notwendigen Durchflussgeschwindigkeit, werden verschiedene Pumpen benutzt.

Gegebenenfalls kann in einer vorteilhaften Ausführung der Erfindung vorgesehen sein, dass die Designpläne für die Rohrleitungen (hergestellt aus Polyethylen von hoher Dichte (HDPE), mit Druckwerten bis zu 1.1 MPa) und der ausgewählte Standort für die Benutzung des geeigneten Weges im Verhältnis zu der CO2-Emission, aufgrund der ganzheitlichen Analyse des Lebenszyklus (LCA) bei jedem einzelnen Projekt gewonnen werden. Das heißt, wenn eine vorhandene Infrastruktur schon besteht, dann wird sie auch genutzt, wie im Fall des ägyptischen Nasser-Sees und des Scheich Zayed-Kanals, welche benutzt werden sollten, und worüber ich folgend reflektieren werde. In anderen Fällen sollte der natürliche freie Fall maximal möglichst integriert / ausgenutzt werden.

Ventile werden zur Überwachung, Sicherheit und Reinigung alle 1000 Meter installiert. Für alle Rohrleitungsdesigns ist die Fluidmechanik des Designs wichtig. Wege zur Überwindung von Anstiegen oder potentielle Gewinnung zusätzlicher Energie kann in den grundlegenden Regeln der Physik gefunden werden, und die Anwendung dieser Regeln fordert eine anspruchsvolle, sorgfältige und berechnete Planung um:
* die Rohrhöhe schnell zu vermindern;

* die Rohrdurchmesser direkt vor der Turbine zu verringern (diese Methode kann auch für die Überwindung von Problemen, welche aufkommen wenn das Bodenniveau plötzlich steigt);
* das Graben von Tunnels für die Überwindung von größeren Anstiegen oder zu anderen Zwecken zu ermöglichen.

Gegebenenfalls kann vorgesehen sein, dass der Kanal aus wasserundurchlässigem Beton umfasst, um Wasserleckagen zu verhindern. Seine Breite von 30 Metern und die maximale Tiefe von 6 Metern ermöglicht, dass der Kanal wegen der hohen Verdunstungsrate in der Nähe des nördlichen Wendekreises riesige

Wassermengen verliert. Das ist der Grund weshalb ich eine Lösung in Form eines Trägers der Rohrleitung konzipiert habe, womit die hohe Verdunstungsrate gestoppt wird. Ich schlage vor eine Metallkonstruktion mit Fundamenten außerhalb der undurchlässigen Betonwände des Kanals zu errichten, aber so nah wie möglich zu der Wand. Die Baufundamente werden aus Doppelsäulen / Fundament, welche im Fundament fundiert und fixiert sind, und aus sekundären Säulen sein und welche sich leicht in die ersten Säulen einpassen und eigentlich die ganze Struktur tragen werden.

Gleichzeitig werden sie frei sein um in ihrer Achse erhöht zu werden, wenn Hochwasser aus dem Stausee des Assuan-Dammes über den Kanal in den Toshka-See geleitet werden muss, sodass das Dach des Objektes nicht durch Überschwemmungen gefährdet ist. Das Dach soll aus Solarpaneelen bestehen, welche in der Lage sind den Strom für die Hauptverarbeitungsanlage und die in der Region neu geplanten Dörfer zur Verfügung zu stellen. Das Dach wird aber auch die Hauptrohrleitung, welche unter das Hauptskelett der Konstruktion gehängt und im Wasser versenkt ist, tragen. Die Hauptrohrleitung soll in diesem Fall dem Verlauf des Kanals, mit den entsprechenden Aussparungen, welche für jeden Standort, der unterwegs bewaldet werden soll, konstruiert sind, folgen.

Gegebenenfalls kann vorgesehen sein, dass die Pläne für die Hauptrohrleitung im Einklang mit den Berechnungen der niedrigsten CO2-Gesamtemission, gewonnen aufgrund der ganzheitlichen Analyse des Lebenszyklus (LCA) bei jedem einzelnen Projekt, sein werden und dass dieses die geographische Positionierung/Orientierung der Rohrleitung beeinflussen wird. Es wird Gebiete geben in denen die geeignetste und billigste Weise darin besteht, die Rohrleitung unter der Bodenoberfläche einzugraben wie beispielsweise in Gebieten, die ausinstabilen Böden oder Sandböden / oder Dünen bestehen.

Gegebenenfalls kann vorgesehen sein, dass die Pläne für die Hauptrohrleitung im Einklang mit den Berechnungen der niedrigsten CO2-Gesamtemission, aufgrund der ganzheitlichen Analyse des Lebenszyklus (LCA) bei jedem einzelnen Projekt, gewonnen sein werden und dass diese die geographische Positionierung/Orientierung der Rohrleitung beeinflussen werden. Es gibt Gebiete, in denen die geeignetste und billigste Weise darin besteht, die Rohrleitung über der Bodenoberfläche zu führen, beispielsweise in Gebieten wo harte Steinwüsten und/oder Oberflächen aus Granitstein bestehen.

Gegebenenfalls kann vorgesehen sein, dass Roboterreiniger für die Reinigung der Rohrleitung benutzt werden sollen. Roboterreiniger sollen aus einer tragenden Metallkonstruktion bestehen, welche verbunden ist um eine halbsteife Linie zu bilden und welche an ihrer Hinterseite einen Motor und einen Propeller besitzt, die ihr das Fortbewegen durch das Rohr ermöglicht. Am Vorderteil besitzt er einen Zugespitzten konkaven Kopf aus dem Bürsten und Drähte herausragen, mit aufeinanderfolgenden Rädern und kreisenden Bewegungen, die sich bis zum genauen Innendurchmesser der Rohrleitung ausbreiten. Diese Roboteranlagen werden sich von einem zum anderen Ventil bewegen und so die Rohrleitung

reinigen.

Gegebenenfalls kann vorgesehen sein, dass der Übergang aus der Haupt- in die Nebenrohrleitung, mit welcher die Sedimenten- und Wassermischung zu den zu bewässernden Feldern gebracht wird, möglich ist, abhängig von den im konkreten See verfügbaren Ablagerungen und der Kraft der Verarbeitungsanlage, und Zwar auf mindestens sieben Kilometern in der Länge auf jeder Seite der Hauptrohrleitung mit mindestens einem Kilometer Abstand von einer Abzweigung zu der Nächsten an der Hauptrohrleitung. Das gleiche Prinzip soll auch bei jeder weiteren Abzweigung der Hauptrohrleitung beim Projekt im Feld benutzt werden.

Gegebenenfalls kann vorgesehen sein, dass das Projekt, abhängig von der geographischen Zusammensetzung des für die Agroforstwirtschaft ausgesuchten Standortgebiets, verschiedene Zugangsweisen zu der Bewässerung haben wird.

Im Fall einer hügeligen Sandwüste mit einer halbfesten Bodenoberfläche (und deshalb vorwiegend aus Sandstein oder einer harten Erdbodenoberfläche) soll das Terrassensystem für die Bewässerung benutzt werden. Das heißt, das Feld soll von Erd-/Steinwänden in einer Höhe von zwanzig bis fünfundzwanzig Zentimetern umgeben und die Feldoberfläche geebnet werden, damit sich die neu ankommende Sediment- Wasser Mischung im Feld gleichmäßig ablagern kann und auf diese Weise die Möglichkeit für das Bilden eines fruchtbaren Erdbodens gegeben wird. Wenn möglich, sollten die Stecklinge sofort gepflanzt und das bewässerte Feld mit dem verfügbaren organischen Material, wie Blätter, Mulch und ähnliches Material bedeckt werden. Die weitere Bewässerung des Feldes soll durch unterirdische Tropfenbewässerung ausgeführt werden.

Im Fall einer hügeligen Sandwüste mit einer halbfesten Bodenoberfläche (und vorwiegend aus steinigem oder einer harten Erdbodenoberfläche) soll das Terrassensystem für die Bewässerung benutzt werden. Das heißt, das Feld soll mit Erd-
/Steinwänden in einer Höhe von zwanzig bis fünfundzwanzig Zentimetern umgeben (und mit Öffnungen zur Überflutung von mindestens 5 cm damit das Feld abfließen kann und so in die nächsten Felder abfließen kann, und somit das nächste Feld durch die Überflutung bewässern kann) und die Feldoberfläche geebnet werden, damit sich die neu ankommende Sediment-Wasser-Mischung im Feld gleichmäßig ablagern kann und auf diese Weise die Möglichkeit für das Bilden eines fruchtbaren Erdbodens gegeben wird Wenn möglich, sollten die Stecklinge sofort gepflanzt und das bewässerte Feld mit dem verfügbaren organischen Material, wie Blätter, Mulch und ähnliches Material bedeckt werden. Die weitere Bewässerung des Feldes soll durch unterirdische Tropfenbewässerung ausgeführt werden.

Im Fall von flachen Sandwüsten mit einer Sandmasse als vorwiegender Bodenoberfläche sollen die Feldgrenzen festgelegt und die ständigen Winde und

ihre Kraft gemessen werden. Danach wird einer von zwei Zugängen angewendet: Roboterumzäunung oder Umzäunung mit einer einheimischen Busch-Art.

Zuerst sei die Umzäunungsmethode mit einer einheimischen Busch-Art beschreiben: um eine dichte Vegetation von Buschhecken einrichten zu können soll man heimische Arten benutzen, und zwar Kakteen als erste Abwehrschicht, dann Bäume wie Akazien, falsche Akazien, Johannisbrotbäume, welche schnell wachsen und in der Wüste heimisch sind, danach folgen Buschbäume der Moringa Familie oder andere schnell wachsende aus der Wüste stammende Buscharten (denn sie verlangen keine großen Bewässerungsmengen). Nach sechs Monaten der regelmäßigen Bepflanzung kann mit der unterirdischen Tropfenbewässerung des Agroforstsystems begonnen werden.
Wenn möglich, sollten die Stecklinge sofort gepflanzt und das bewässerte Feld mit dem verfügbaren organischen Material, wie Blätter, Mulch und ähnliches Material bedeck werden. Die weitere Bewässerung des Feldes soll durch unterirdische Tropfenbewässerung ausgeführt werden.

Wenn die Winde sehr stark sind, ist für die ersten fünf bis zehn Jahre ein Solarroboterschild zu errichten, abhängig vom konkreten System und der für die Bepflanzung ausgewählten Art. Eine einfache Struktur in Form eines Zauns, gebildet aus Windturbinen um den Wind zu verlangsamen und dann einem teleskopischen, hydraulischen Roboterträger von Solarpaneelen, der weiters für den Schutz des Feldes benutzt werden kann.

Diese speziell konzipierten Solarpaneele sind halbtransparent, robotisch und von einer Schicht umgeben, welche sie vor der Beschädigung infolge der aufgefangenen Wasserverdunstung schützt. Die Windgeneratoren und Solarpaneele werden vor allem als erste Abwehrlinie gegen starke Wüstenwinde benutzt. Die Solarpaneele bilden eine dreifache Schutzlinie. Erstens, werden sie als Sandstopper benutzt und reagieren als Schilde, programmiert mit Algorithmen, die Signale aus den umgebenden Wetterstationen und den Sensoren vor Ort, welche die Intensitätsveränderung des Windes messen, empfangen, und das Solarpaneel in eine Schutzformation umwandeln, wenn sich ein Sandsturm nähert und auf diese Weise verhindern, dass der Schwer erschlossene Erdboden wieder zu Sand wird. Zweitens, die Solarpaneele werden als Schutz vor der Sonne benutzt, da sie halbtransparent und so gebaut sind, dass sie der Sonne angepasst werden können um so viel wie möglich von der Sonnenenergie zu absorbieren, wenn sich die Sonne im Scheitelpunkt befindet, gleichzeitig den Pflanzen ermöglichend die Sonne zu nutzen, wenn ihre Strahlen schwächer sind. Auf diese Weise werden die Pflanzen vor Sonnenbrand der Wüstensonne geschützt bevor die robusteren Arten, welche in der Wüste gedeihen, sich voll etabliert haben, aber trotzdem ist es den Pflanzen ermöglicht die Sonne für die Photosynthese zu benutzen.

Der dritte Benutzungszweck der Solarpaneele ist das Aufsammeln der Verdunstungen mit Hilfe ihrer speziell konzipierten wasserfesten Hinterseite,

was den Landwirten ermöglicht dieses Wasser wieder für die Bewässerung zu verwenden. Für die neu gegründeten Dörfer des 21. Jahrhunderts wird mit ihnen auch der notwendige Strom besorgt. Wenn möglich, sollten die Stecklinge sofort nach der Konstruktion dieses

Robotersystems gepflanzt und das bewässerte Feld mit dem verfügbaren organischen Material, wie Blätter, Mulch und ähnliches Material bedeckt werden. Die weitere Bewässerung des Feldes soll durch unterirdische Tropfenbewässerung ausgeführt.

Es ist bekannt, dass der Zugang Save and Grow (Bewahren und Anbauen) der UN-FAO am nächsten zu der konventionellen Landwirtschaft steht, wobei der biodynamische Zugang am entferntesten davon ist. Durch die Auswahl der wichtigsten Elemente aus diesen Herangehensweise beruht mein konservierender agroforst- landwirtschaftlicher Zugang zur erfolgreichen Begrünung der Wüste auf den oben angeführten Zugängen und auf den anderen anerkannten Zugängen zur Wüstenbegrünung, die alle in einem einzigen Zugang vereint wurden, der in Kombination mit meinem Transportsystem für die Seereinigung am besten den Wüstenbedingungen entspricht.

Vom agro-ökologischen Standpunkt betrachtet ist mein Zugang eigentlich ein System für die Beobachtung der Zugänge und die Vermessung und Berechnung ihrer Tauglichkeit – das ist der Standpunkt, den ich einnehme. Eine Agroökologie, die zukünftige Adaptionen und Änderungen sowie einen klaren wissenschaftlichen Zugang, der sich auf messbare Angaben und bewiesene erfolgreiche Praktiken und Politiken stützt. Einige Merkmale der älteren Zugänge, die in vielen verschiedenen Herangehensweisen angenommen wurden, sind auch miteinbezogen, da sie breit anerkannt sind, wie z.B. Keyline-Design, Polykultur und Samenbomben (Clay Seed Balls). Genetisch modifizierte Organismen sind weit verbreitet abgelehnt und die verfügbaren Daten aus unabhängigen Quellen sind nicht ausreichend um irgendeine Schlussfolgerung betreffend der Richtung ihrer Benutzung in freien Öko-Systemen zu ziehen.

Deshalb wurde beschlossen sie vollkommen auszuschließen solange weitere Forschungen nicht zur Verfügung stehen. Mein Zugang setzt sich aus folgendem zusammen: Während der Fokus auf den Schlüsselprinzipien der Sorge um Menschen, Umwelt und wirtschaftliche Machbarkeit stehen, ist mein Zugang der Öko- Landwirtschaft und der Permakultur am ähnlichsten und betrachtet die Agroforstwirtschaft als Schlüsselfeld des Profits, da der Großteil des Bodens in Wälder nach den Regeln der Öko-Landwirtschaft und der Permakultur umgewandelt wird. Dabei werden die Regeln der Internationalen Vereinigung der ökologischen Landbaubewegungen (IFOAM) geachtet und alle Produkte, welche gemäß den sehr klaren Regeln der ökologischen Landbaubewegung gewonnen sind, werden registriert.

Da IFOAM schon sehr klare und eindeutige Regeln, welche Landwirte Zu befolgen haben, gestellt hat, können sich einige in andere Richtungen entwickeln, sodass

ich der Meinung bin, dass es von größter Bedeutung dass sich jemand als Bioanbauer registriert, wenn er einem dieser landwirtschaftlichen Zugänge angehört, denn organisches Wissen und Erfahrung stellen eine solide Grundlage dar, auf der man den Ausbau von gesunden und nachhaltigen landwirtschaftlichen Systemen für die Zukunft beginnen kann. Der Fokus auf die direkte Aussaat ohne vorhergehende Bearbeitung (no-till) sollte betont werden, denn in Wüstenbedingungen trägt die tatsächliche Entstehung von Erdboden die Schlüsselrolle des Fortschritt des Projekts – das Erhalten einer ständigen organischen Decke des Bodens während dem ganzen Jahr wird nicht nur zu der Erhöhung des organischen Materials beitragen, sondern auch die erhöhte Verdunstungsrate in der Wüste effektiv verhindern.

Die Erhöhung der Biodiversität wird durch die Benutzung eines permakulturellen Zugangs zur Bepflanzung von verschiedenen Arten bestehen, mit der Tendenz immer örtliche und hoch angepasste Arten mit großen Erträgen zu benutzen, die eine hohe Toleranz gegen Trockenheit besitzen und in mindestens sieben Waldschichten gepflanzt werden. In dieses Projekt werden auch Tierzucht und das holistische System für die Beweidung durch Rindern von Allen Savvory einbezogen, wiederum mit Benutzung von Arten, welche heimisch oder an die Trockenheit schon angepasst sind. Poly- und Mischkultur sind wesentliche Bestandteile dieses Zugangs, da diese zwei separaten Zugänge soweit angenommen sind, dass ihre Merkmale einbezogen sind, obwohl sie als eigene Zugänge angesehen werden.

Das Keyline-Design wird nicht so sehr für das Sammeln von Regenwasser benutzt, sondern für die Bewahrung des Wasserüberschusses nach der Bewässerung in Kombination mit den Holzer Hügelkulturbeeten aus verfügbarem Holzmaterial, wenn der Standort in der Lage ist dieses Material zu bereitzustellen. Wenn solches Material nicht verfügbar ist, kann diese Funktion mit Hilfe der vor kurzem abgeschnittenen Äste der Bäume aus der Familie Moringa erfüllt werden, da deren Beschneidung den Wurzeln hilft, Leben für Bakterien und Mikroorganismen aufkeimen zu lassen. Um in der Wüste produktiv zu sein, gibt es keinen Raum für Abfälle, da jedes Pflanzen- und Tierteil für die Verbesserung des organischen Anteils im Boden benutzt wird. Im Kontext der Bodenbereicherung wird an bestimmten Standorten Tonerde reichlich zur Verfügung stehen und für diese Standorte wird die Benutzung von Samenbomben (Clay Seed Balls) empfohlen, da erwiesen ist, dass ein höherer Tonanteil im Erdboden die Bodenfruchtbarkeit erhöht, besonders in Wüsten, da er den Erdboden gegen Trockenheit widerständiger macht.

Durch die Berücksichtigung des konservierenden bodenschonenden Zugangs basieren einige Merkmale dieses Systems auf dem Zugang Save and Grow der Ernährungs- und Landwirtschaftsorganisation (Bewahren und Anbauen), da er drei Punkte enthält, die für dieses gegenwärtige System sehr passend sind. Die Benutzung von Sorten mit hohem Ertrag aus einem Vorrat an guten Samen wird das Anfangskeimen ermöglichen, aber die Landwirte werden ermutigt ihre Saat auf zu bewahren und die eigenen Sorten zu verwenden (gleichzeitig besitzen sie

Wissen und Fähigkeit die vorhergehenden Saatvorräte zu benutzen). Das in der Permakultur integrierte Schädlingsmanagementsystem (gleichzeitig ein wichtiger Faktor in der Methode „ohne Chemikalien“ ist) besteht in der Planung der Zugabe von Nährstoffen in den Boden, der vorher getestet ist, sodass man weiß welche Additive eigentlich notwendig sind und welche Pflanzen diese bereitstellen können.

In Teilen des Agroforstsystems, welches reheinweise gepflanzt ist (alley cropping parts), wird zwischen den Bäumen sowie auf allen Zur Verfügung stehenden neugewonnen Weideflächen das crop-pasture System empfohlen, da jede in diesem Komplex verwendete Praxis nicht nur einem Zweck, sondern mehreren Zwecken in einem sehr einfachen Zugang erfüllen soll, der versucht in 100 Jahren selbsterhaltend zu sein und die Wüste zu übernehmen soll.

Wenn gewünscht ist, dass irgendein Bewaldungsprojekt erfolgreich, nachhaltig und selbstständig sein soll, darf es sich nicht auf das menschliche Eingreifen stützen. Damit meine ich, dass die Projektinvestoren Systeme schaffen sollen, welche den Erdboden entwickeln und über die Notwendigkeit nach Bewässerung herauswachsen indem sie ein für die Lebenserhaltung im Erdboden sowie für das eigentliche Bewaldungssystem ein adäquates Mikroklima schaffen.

Ich schlage die Möglichkeit vor, Bildung zu verwenden um dies zu erreichen und die örtlichen Bevölkerung so einzubinden, dass sie sich mit den gepflanzten Bäumen befasst und sie durch praktischen Methoden die Verwaltung von erfolgreichen Agroforstsystemen von der Saat und dem Saatmaterial bis zu der vollen Entwicklung zu lehren. Das wird auch das Übertragen von Wissen, darüber welche Pflanzen zusammen gepflanzt werden sollen und wie dieses zu machen ist, beinhalten. Das Projekt wird auch einen praktischen Wissenszugang zur Integration der lokalen Bevölkerung in das Leben des Projektes und der Agroforstsysteme benutzen, und sie über die Vorteile von nichthölzernen Produkten des Waldes und von der Pflanzung von Mischkultur in der Wüste lehren. Die Menschen werden gelehrt, die Bäume nicht zu fällen, was dem Wald und dem Erdboden ermöglicht unabhängig zu wachsen und aus dem Bedürfnis nach Bewässerung herauszuwachsen.

Weitere Merkmale der Erfindung sind den Figuren, den Patentansprüchen und den allgemeinen Beschreibungsseiten zu entnehmen.

Es zeigen:

Fig. 1: Ein Ausführungsbeispiel einer erfindungsgemäßen Anlage.

Fig. 2: Ein weiteres Ausführungsbeispiel einer erfindungsgemäßen Anlage. Fig. 3: Ein weiteres Ausführungsbeispiel einer erfindungsgemäßen Anlage.
Fig. 4: Ein Ausführungsbeispiel eines Saugbootes mit schwimmenden Solarpaneelen. Fig. 5: Eine Illustration der Sedimentsammlung in einem

erfindungsgemäßen Ausführungsbeispiel.
Fig. 6: Eine Illustration von mit Solarpaneelen abgedeckten Rohrleitungen. Fig. 7: Ein Ausführungsbeispiel eines Reinigungsroboters.
Fig. 8: Eine Illustration der Verzweigung von Rohrleitungen gemäß der vorliegenden Erfindung.
Fig. 9a: Die Detailansicht eines Ausführungsbeispiels.

Fig. 9b und c: Die Detailansicht von Terrassenstrukturen eines erfindungsgemäßen Ausführungsbeispiels.
Fig. 10: Eine Illustration von erfindungsgemäßen Windschutzvorrichtungen.

Die Figuren stellen bevorzugte Ausführungsformen der vorliegenden Erfindung dar.

Fig. 1 zeigt: Staudamm 11; Baggerschiff/-boot 12; See 13; gebildeter Sedimentfluss 14; Baggerschiff 15, angetrieben mit Solar- und/oder Windenergie; Baggerschiff 16, angetrieben mit Solarenergie verbunden mit einem Floß ohne Antrieb, das ein Dach aus Solarpaneelen besitzt; Transportrohleitung 17 von den Baggerschiff bis zu der Verarbeitungsanlage; Schiff ohne Antrieb 18 mit einem Dach aus Solarpaneelen, welche das Baggerschiff antreiben; Solarpaneele 19 auf dem Dach der Verarbeitungsanlage; Verarbeitungsanlage 110; Hauptrohrleitung 111;
Nebenrohrleitung 112; Agroforstfelder 113; Schutzvorrichtungen 114 für Agroforstfelder.

Figur 2 zeigt: Staudamm 21; Baggerschiff 22; See 23; gebildeter Sedimentfluss 24; schwimmende Rohrleitung 25, welche den Bagger mit der Hauptverarbeitungsanlage verbindet; Solarpaneele 26 auf dem Dach der Verarbeitungsanlage 27; Verarbeitungsanlage 27; Hauptrohrleitung 28; Nebenrohrleitung 29;
Schutzvorrichtungen 210 für Agroforstfelder; Agroforstfelder 211; Solarpaneele 212 auf dem Dach des Baggerschiffs/-boots; Windturbinen 213 auf dem Dach des Baggerschiffs/-boots.

Figur 3 zeigt: Staudamm 31; See 32; Wehrdamm 33; Saugpumpe 34 an der Tunnel-

/Rohrleitungsöffnung; Unterwasserteil 35 der Tunnel-/Rohrleitung; Tunnel-/Rohrleitung 36 auf dem Land; Verarbeitungsanlage 37; Solarpaneele 38 auf dem Dach der Verarbeitungsanlage; Hauptrohrleitung 39; Nebenrohrleitung 310; Schutz 311 von
Agroforstfeldern; Agroforstfelder 312.

Figur 4 zeigt: Schwimmende Trägerstruktur 41 für Solarpaneele; schwimmende Solarpaneele 42; Zieh- und Verbindungsleinen 43; Baggerschlauch 44; Saugbagger/Saugkopf 45; Baggerschiff 46, angetrieben mit Solar- und

Windenergie; Solarpaneele 47; Windturbinen 48.

Figur 5 zeigt: Bildung des Sedimentflusses 51; See 52; Wehrdamm 53; Tunnel-/Rohrleitung 54; Verarbeitungsanlage 55; Hauptrohrleitung 56; Staudamm 57; neue Bildung des Sedimentflusses 58; Saugpumpe 59 an der Tunnel-/Rohrleitungsöffnung.

Figur 6 zeigt: freier Raum 61 für Hochwasser; boxförmiges, hohles Fundament 62 mit doppeltem Box-Querschnitt; Struktur 63, welche den quer geschnittenen Kasten des zweiten Fundaments trägt; Trägersäule 64 aus rostfreiem Stahl, quer geschnittener hohler Kasten; verfügbare Bewegungen 65 mit der Erhöhung des Überschwemmungswassers; tragende Konstruktion 66 für die Hauptrohrleitung, welche ins Wasser versenkt werden soll, fixiert an die tragende Kanaldachstruktur der Solarpaneele; Öffnung 67 in der Konstruktion des Kanalsolardaches bei jedem Kilometer zur Kontrolle der Rohrleitung und der Ventile; Hauptrohrleitung 68; Solarpaneele 69, welche als Dach über dem Kanal verwendet werden um die hohe Verdunstungsrate zu verhindern.

Figur 7 zeigt: Parabolischer Kegelkopf 71 des Roboters für die Rohrleitungsreinigung; verbundene Bürsten 72 und Besen 72 für das Reinigen; batteriegetriebener Motor 73, welcher den Roboter antreibt; Propeller 74; tragende Metallkonstruktion 75 aus rostfreiem Stahl verbunden in steifer Linie mit der Naht; verstellbare Sprungfeder 76 zur leichteren Bewegung in der Rohrleitung.

Figur 8 zeigt: Hauptrohrleitung 81; Nebenrohrleitung 82 (sekundäre Rohrleitung); tertiäre Rohrleitung 83; Kontrollventile 84, auf alle 1000 m oder mehr, abhängig von den verfügbaren Sedimentablagerungen, welche auch als Eingang für die Reinigung des Roboters in die Rohrleitung benutzt wird.

Figur 9a zeigt: Dominante Winde 97; erster Schutz 98 vor Wind, Kakteenzaun 2-3 m Pflanzbreite; Akazienbäume 99 als zweiter Schutzzaun gegen den Wind, drei Reihen; Gebüsche100 aus der Familie Moringa als erster Schutz innerhalb des Feldes; Agroforstfelder 93.

Figur 9b zeigt: 5-10 cm Löcher 91 für den Überlauf an den Terrassenwänden; Terrassenwand 92, errichtet aus örtlich verfügbarem Material; Agroforstfelder 93; Endrohrleitung 94, welche die Sediment-Wasser-Mischung zu diesen Feldern bringt.

Figur 9c zeigt: Terrassenwand 92, errichtet aus örtlich verfügbarem Material; unterirdische Tropfenbewässerung 95; Agroforstfelder 93; Endrohrleitung 94, welche die Sediment-Wasser-Mischung zu diesen Feldern bringt und unterirdische Tropfbewässerungssysteme; Rohrleitung 96, welche alle verschiedenen Erhöhungen zwischen den Terrassenfeldern verbindet und die Sediment-Wasser-Mischung verteilt.

Figur 10 zeigt: Agroforstfelder 101; dominante Winde 102; Turbinen 103 angetrieben vom Wind, positioniert in geeigneter Form um die Windstärke abzuschwächen; hydraulischer Roboterteleskopträger 104 von Solarpaneelen, welcher verlängert werden kann; Hauptkörper 105 des Roboterträgers der Solarpaneele, hergestellt aus Material geeignet für die Teleskopstruktur und welches örtlich ausreichend zu finden ist.

Patentansprüche

1. Verfahren zur Bereitstellung von land- und forstwirtschaftlich verwendbaren Wachstumsflächen in hyperariden, ariden und semiariden Wüsten, wobei auf den Wachstumsflächen ein Wachstumssubstrat aufgebracht wird, wobei das Wachstumssubstrat Sedimentablagerungen aus Gewässern, wie Seen oder Flüssen, enthält oder daraus besteht, und wobei die Sedimentablagerungen und der pumpfähige Schlamm in abgedeckten Kanälen oder Röhren transportiert wird, dadurch gekennzeichnet, dass die Sedimentablagerungen aus dem Gewässer abgebaut, gemahlen oder zerkleinert, eventuell gesiebt und in einer Verarbeitungsanlage, mit Wasser zu einem pumpfähigen Schlamm vermischt und der Schlamm auf die Flächen aufgetragen wird.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, dass die Sedimentablagerung auf eine Partikelgröße kleiner als 0,2 mm zerkleinert wird.

3. Verfahren nach einem der Ansprüche 1 bis 2, dadurch gekennzeichnet, dass zur Herstellung des pumpfähigen Schlammes ein Gewichtsverhältnis Sediment : Wasser von 20:80 bis 40:60 unter Beachtung des Lehmgehalts der Sedimentablagerung eingestellt wird, wobei die Bestimmung des Lehmgehalts vorzugsweise mit optischen Verfahren erfolgt.

4. Verfahren nach einem der Ansprüche 1 bis 3, dadurch gekennzeichnet, dass die zum Transport des pumpfähigen Schlamms verwendeten Röhren wenigstens bis
1.1 MPa druckbeständig sind.

5. Verfahren nach einem der Ansprüche 1 bis 4, dadurch gekennzeichnet, dass die zum Transport des pumpfähigen Schlamms verwendeten Röhren mit Roboterreinigern gesäubert werden.

6. Verfahren nach einem der Ansprüche 1 bis 5, dadurch gekennzeichnet, dass die Gewinnung der Sedimentablagerung mittels Saugbagger oder Schwimmbagger

erfolgt, welche vorzugsweise mit Windenergie und/oder Solarenergie betrieben werden.

7. Verfahren nach einem der Ansprüche 1 bis 6, dadurch gekennzeichnet, dass die abgebaute Sedimentablagerung vor dem Weitertransport zur Verarbeitungsanlage vorzerkleinert und vorgesiebt wird.

8. Verfahren nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, dass zur Gewinnung der Sedimentablagerung von einem Flussbett oder vom Boden eines durchströmten Gewässers Schlammdämme zum Leiten und Auffangen der Sedimentablagerung angeordnet werden.

9. Verfahren nach einem der Ansprüche 1 bis 8, dadurch gekennzeichnet, dass die mit dem Wachstumssubstrat versehenen Wachstumsflächen bepflanzt und bewässert werden.

10. Verfahren nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, dass die Wachstumsflächen mit Wänden seitlich abgedichtet werden.

11. Verfahren nach einem der Ansprüche 1 bis 10, dadurch gekennzeichnet, dass die Wachstumsflächen nach Ausbringung des Saatguts mit einem verdunstungshemmenden Mittel, vorzugsweise mit Rindenmulch, abgedeckt werden.

12. Verfahren nach einem der Ansprüche 1 bis 11, dadurch gekennzeichnet, dass mindestens zwei Wachstumsflächen terrassenförmig übereinander angeordnet sind.

13. Verfahren nach einem der Ansprüche 1 bis 12, dadurch gekennzeichnet, dass die Bewässerung der Wachstumsflächen nach Ausbringung des Wachstumssubstrats durch Tropfbewässerung, vorzugsweise durch unterirdische Tropfbewässerung erfolgt.

14. Anlage zur Bereitstellung von land- und forstwirtschaftlich verwendbaren Wachstumsflächen in hyperariden, ariden und semiariden Wüsten, dadurch gekennzeichnet, dass die Anlage eine Sedimentabbauvorrichtung, ein erstes Transportmittel, eine Verarbeitungsanlage und ein zweites Transportmittel umfasst, wodurch das abgebaute Sediment als Wachstumssubstrat auf Wachstumsfläche aufgebracht werden kann.

15. Anlage nach Anspruch 14, dadurch gekennzeichnet, dass die ersten und zweiten Transportmittel Röhren oder nach oben abgedeckte Kanäle sind.

16. Anlage nach Anspruch 15, dadurch gekennzeichnet, dass zum Transport des Schlamms durch die Röhren Schlammpumpen vorgesehen sind.

17. Anlage nach Anspruch 14, dadurch gekennzeichnet, dass das erste Transportmittel ein Schiff oder Kahn ist.

18. Anlage nach Anspruch 14, dadurch gekennzeichnet, dass die Sedimentabbauvorrichtung ein Saugbagger oder Schwimmbagger ist.

Wien, am 13. April 2018

Vesela Tanaskovic
vertreten durch
Puchberger & Partner Patentanwälte

Zusammenfassung

Die Erfindung betrifft ein Verfahren zur Bereitstellung von land- und forstwirtschaftlich verwendbaren Wachstumsflächen in hyperariden, ariden und semiariden Wüsten, wobei auf den Wachstumsflächen ein Wachstumssubstrat aufgebracht wird, wobei das Wachstumssubstrat Sedimentablagerungen aus Gewässern, wie Seen oder Flüssen, enthält oder daraus besteht, und wobei die Sedimentablagerungen und der pumpfähige Schlamm in abgedeckten Kanälen oder Röhren transportiert wird, und wobei die Sedimentablagerungen aus dem Gewässer abgebaut, gemahlen oder zerkleinert, eventuell gesiebt und in einer Verarbeitungsanlage, mit Wasser zu einem pumpfähigen Schlamm vermischt und der Schlamm auf die Flächen aufgetragen wird. Ferner betrifft die Erfindung eine Anlage zur Bereitstellung von land- und forstwirtschaftlich verwendbaren Wachstumsflächen.

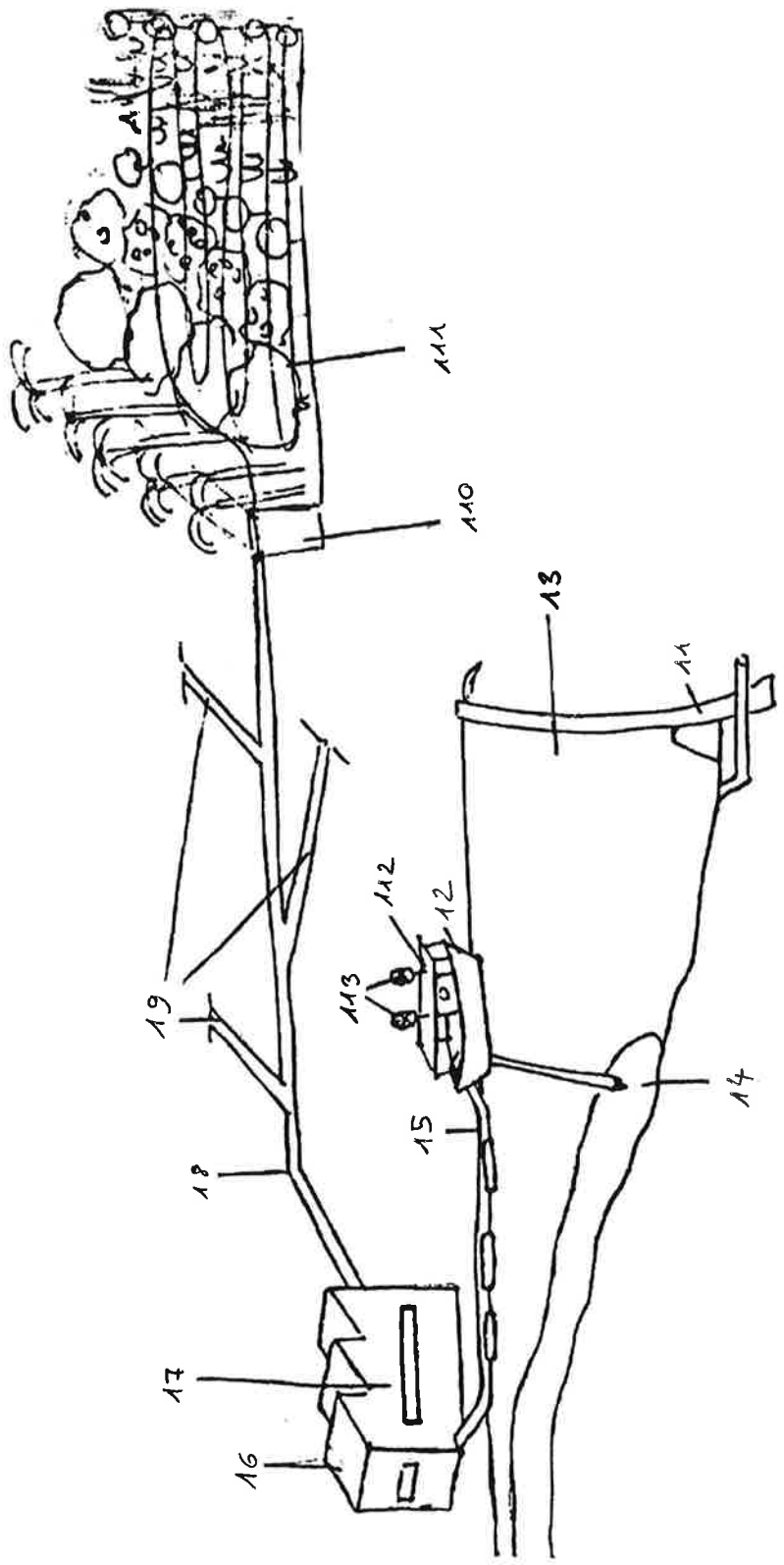


Fig. 1

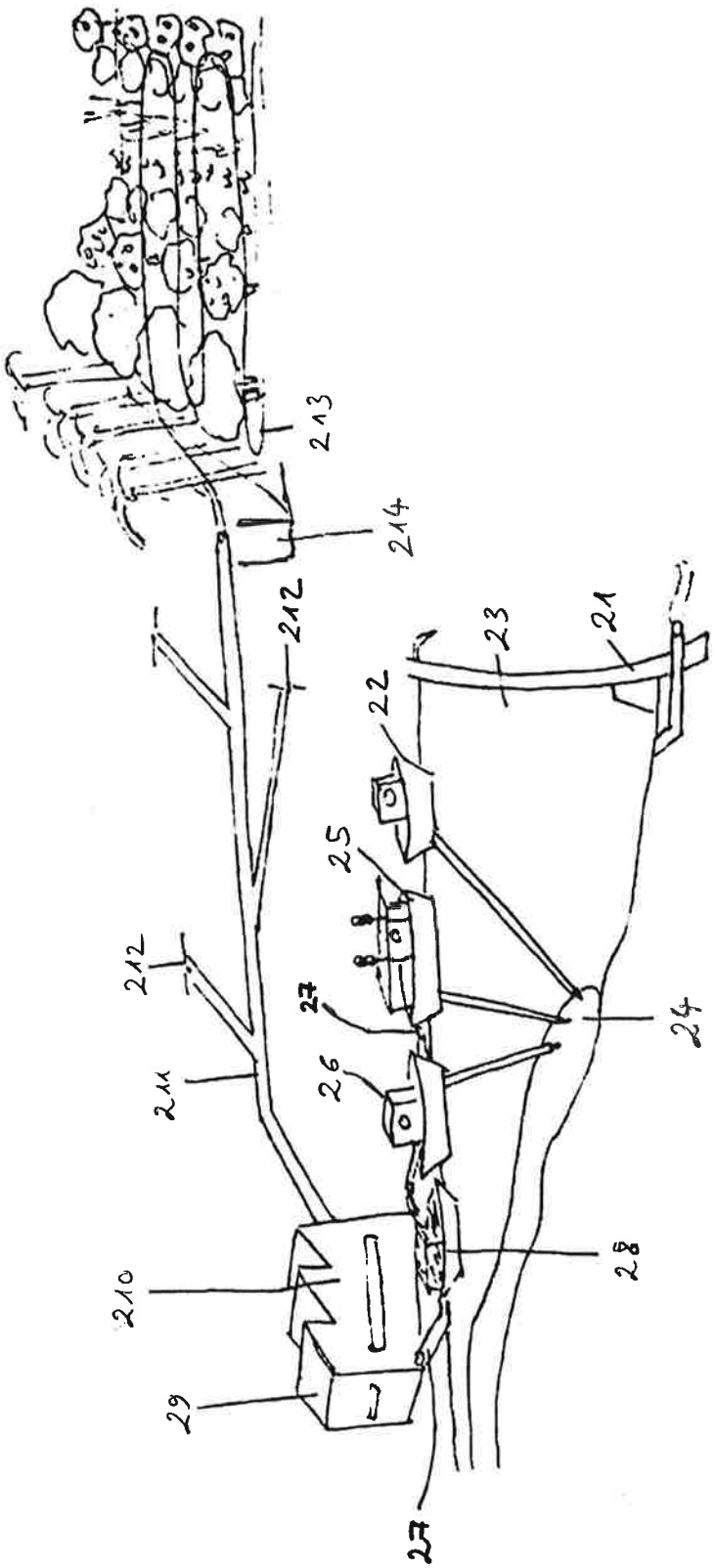
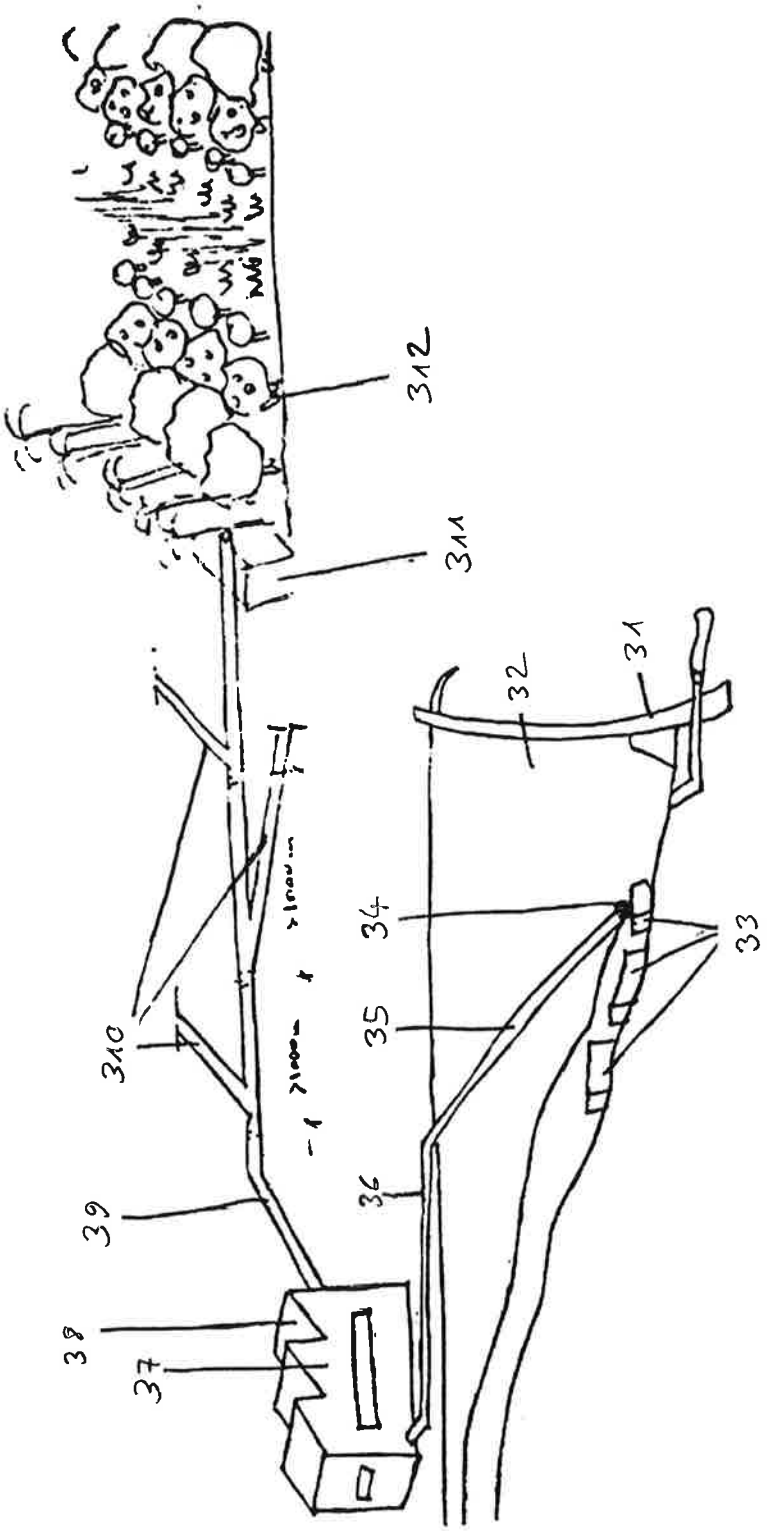


Fig. 2



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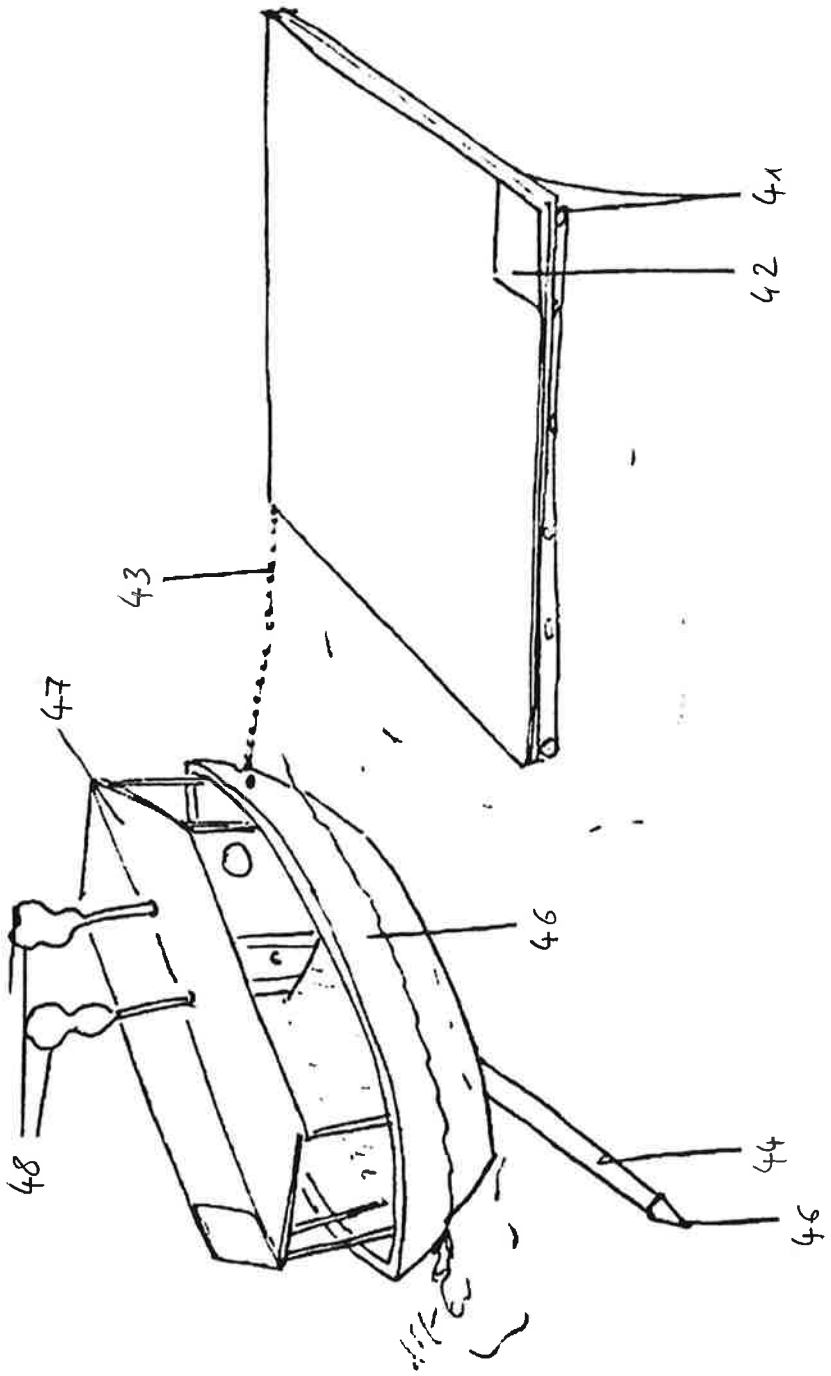
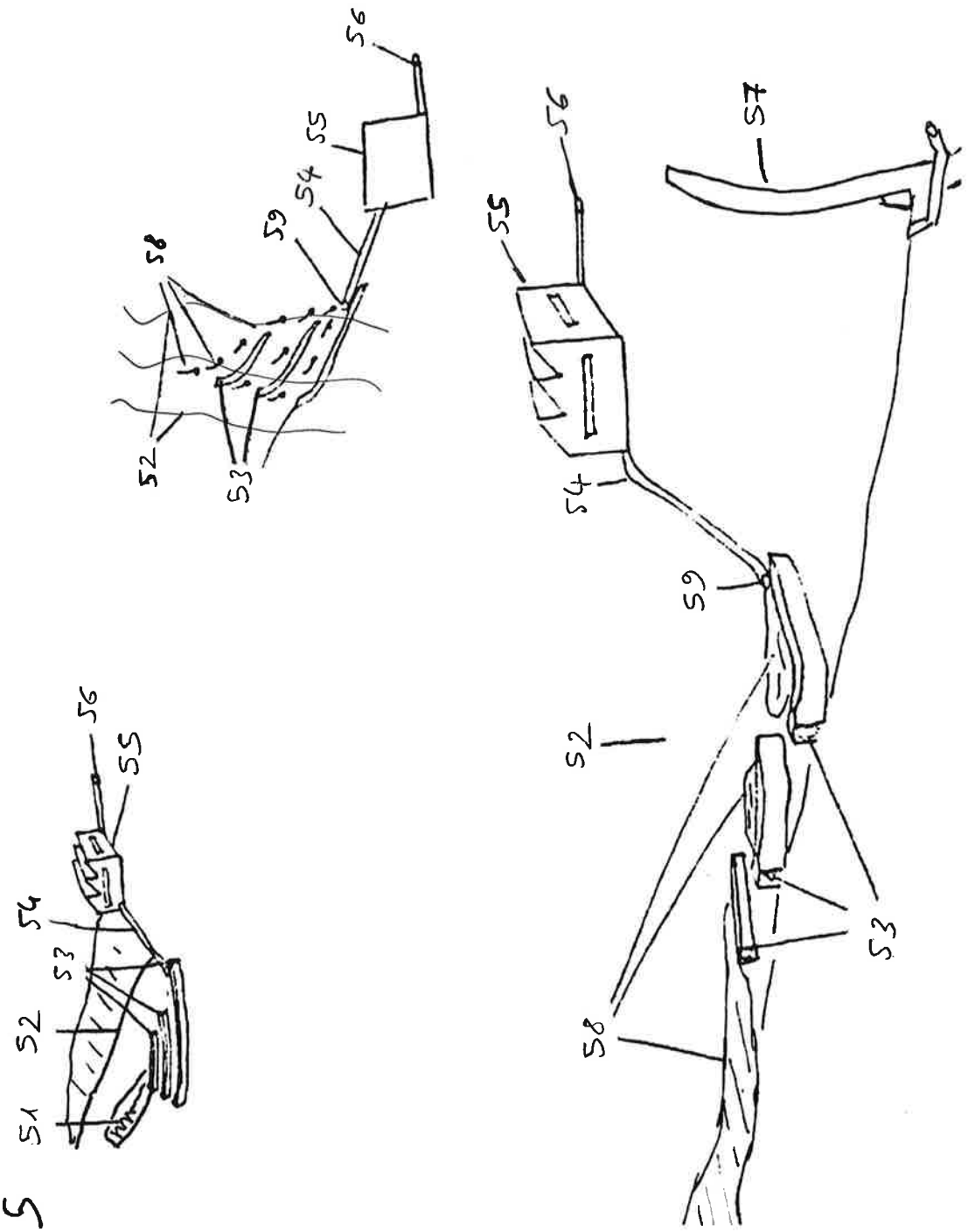


Fig. 4



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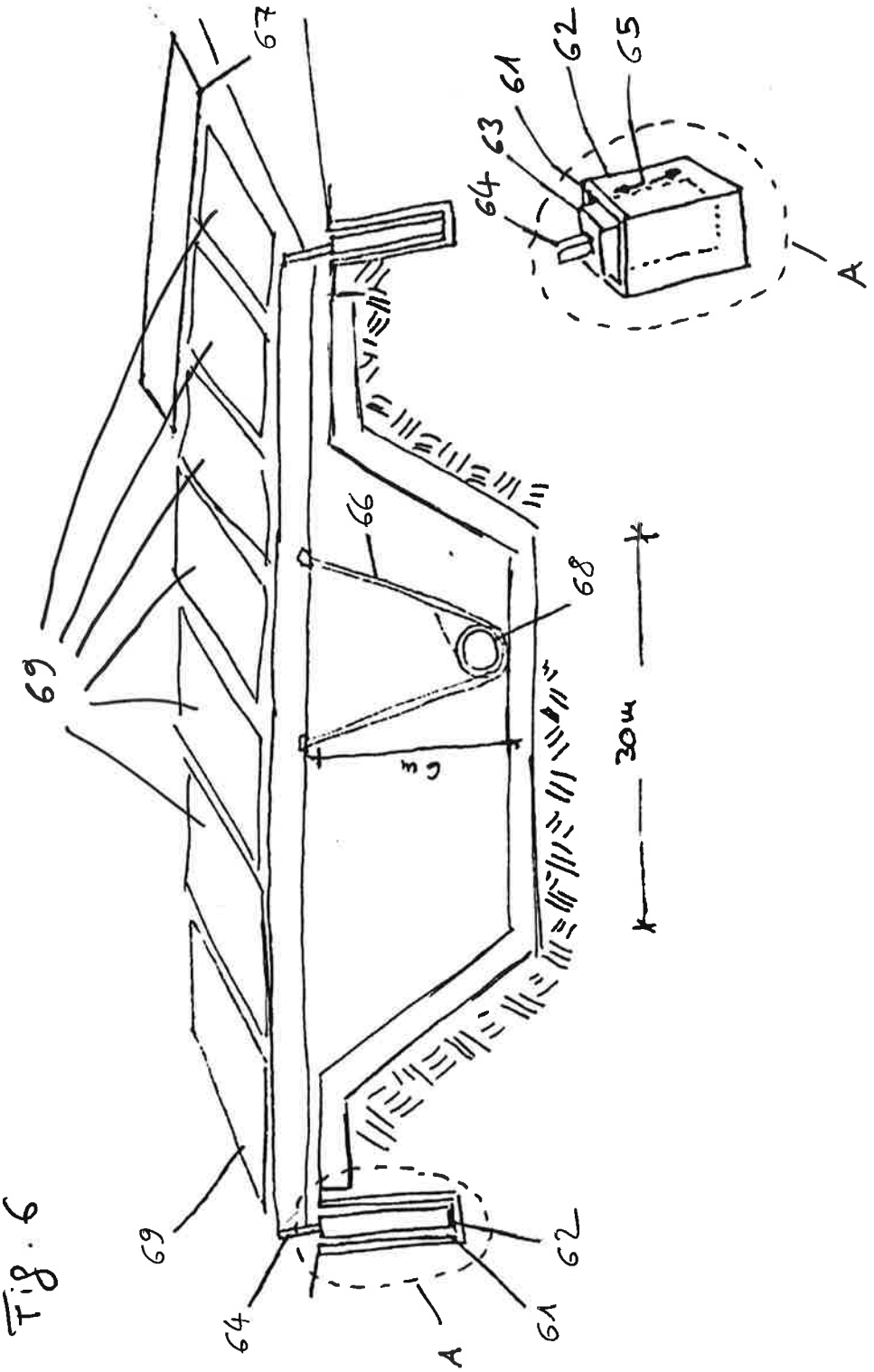

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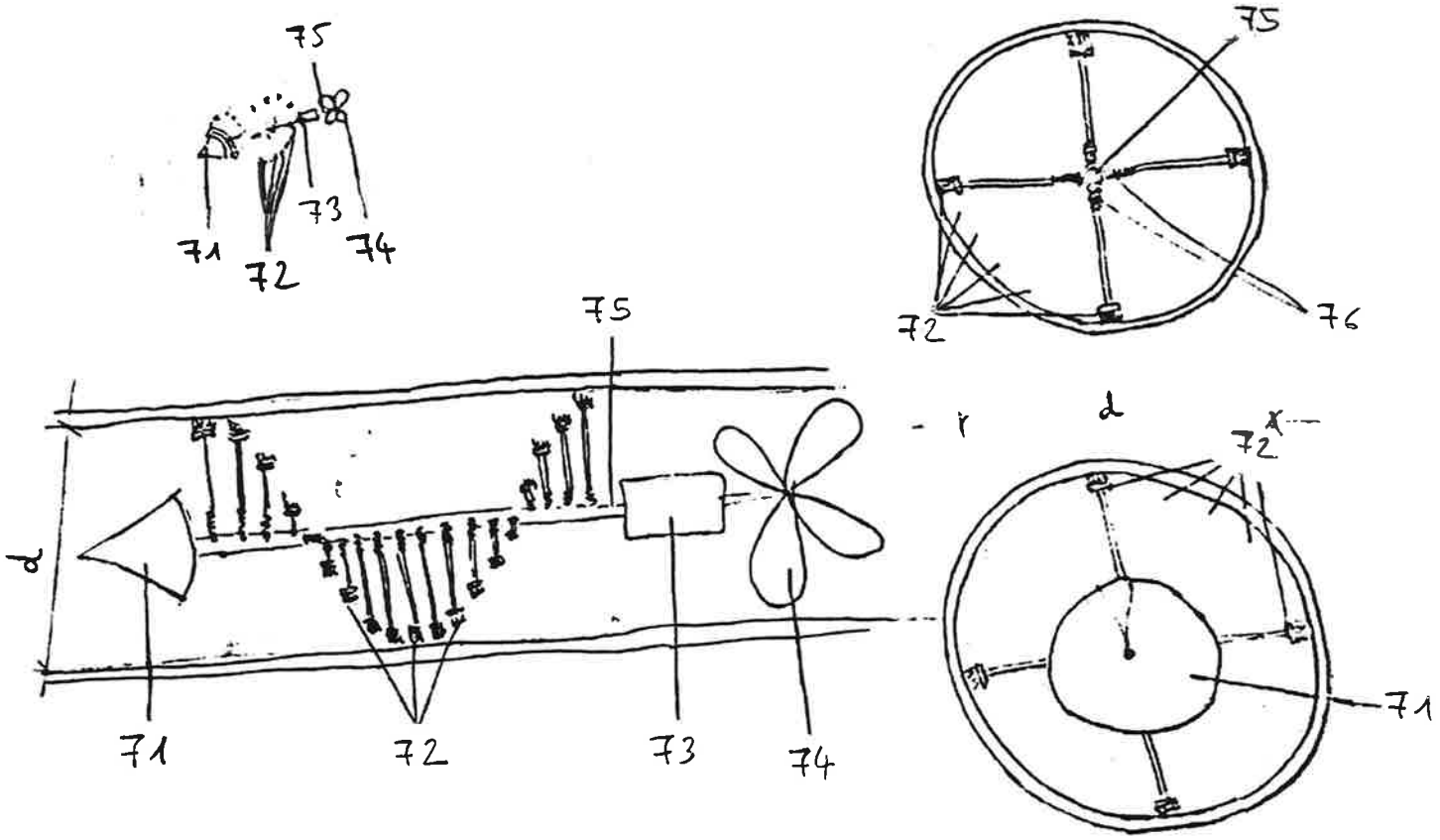

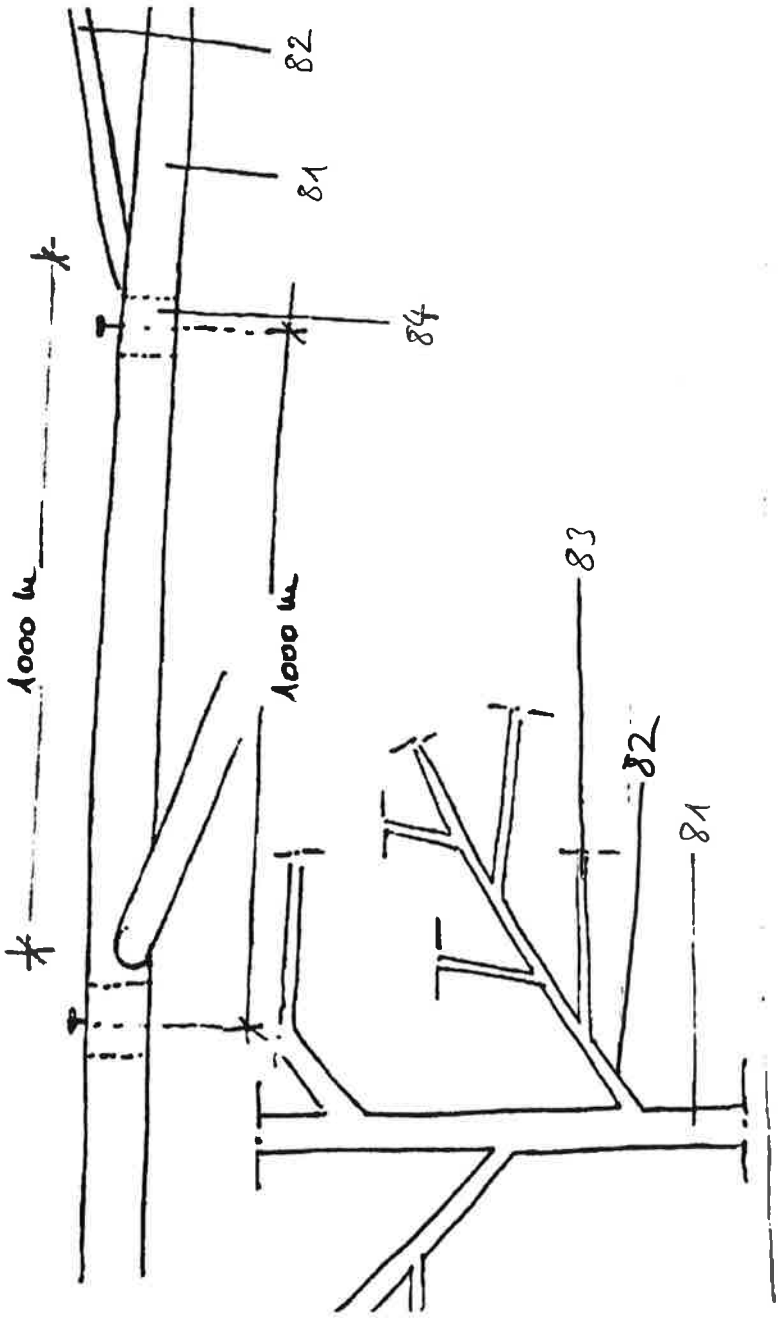

Fig. 8

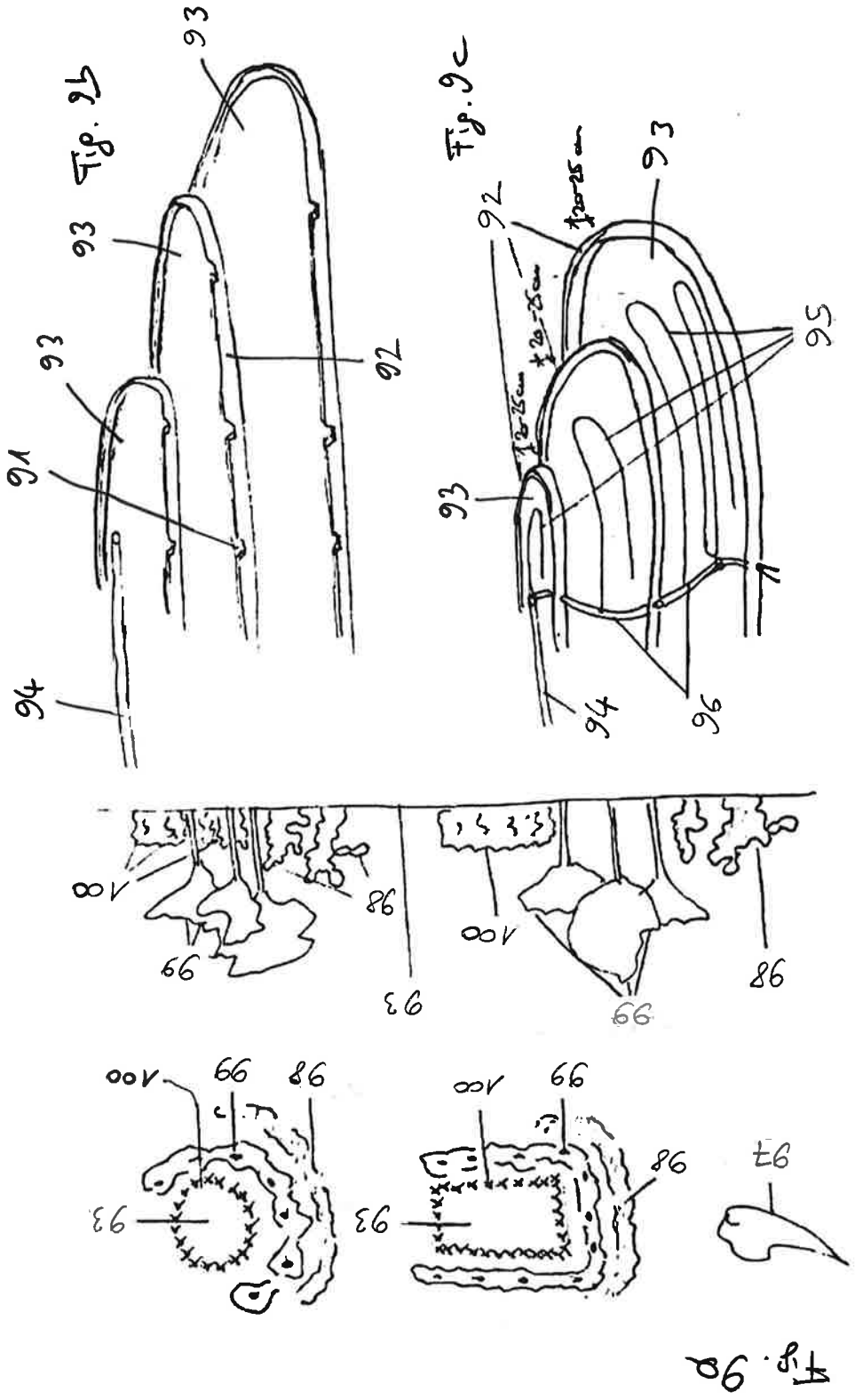
Fig. 9b
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Fig. 9c
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Fig. 9a

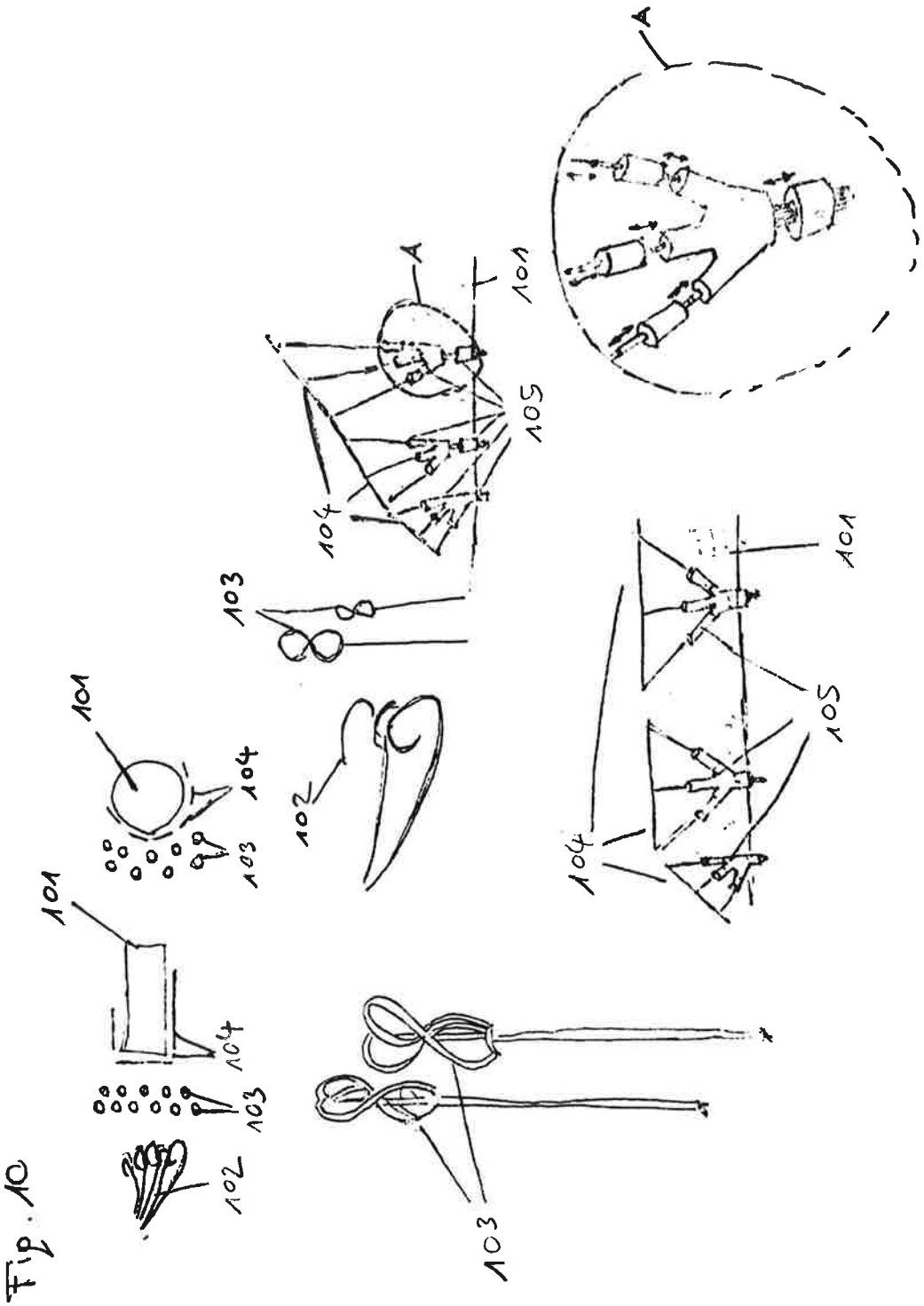
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Fig. 10

Methodology for a sustainable afforestation in semiarid, arid, and hyperacid regions, consisting essentially of a use of dredging systems, transportation pipelines and agroforestry, followed by intense education of local population on agroforestry in order to achieve a maximum sustainability effect. Description of the system:

ANEX I – Translation of the patent and drawings

1. A process for the provision of growth areas available for agriculture and forestry in hyperarid, arid and semiarid deserts, a growth substrate being applied to the growth surfaces, characterized in that the growth substrate contains or consists of sediment deposits from waters such as lakes or rivers.

2. Process according to claim 1, characterized in that the sediment deposits are mined from the waters, ground or shred, possibly sieved, and mixed with water in a processing plant to a pumpable sludge, and the sludge then being applied to the surfaces.

3. Process according to claim 1 or 2, characterized in that the sediment deposit is preferably ground to a particle size of less than 0.2 mm.

4. Process according to one of the claims 1 to 3, characterized in that a weight ratio of sediment: water of 20:80 to 40:60 is adjusted for the production of the pumpable sludge, taking into account the clay content of the sediment deposit, wherein the determination of the clay content is preferably carried out using optical methods.

5. Process according to one of the claims 1 to 4, characterized in that the sediment deposits and the pumpable sludge are transported in covered channels or tubes.

6. Process according to one of the claims 1 to 5, characterized in that the tubes used for transporting the pumpable sludge are pressure-resistant at least up to 1.1 MPa.

7. Process according to one of the claims 1 to 6, characterized in that the tubes used for transporting the pumpable sludge are cleaned with robotic cleaners.

8. Process according to one of the claims 1 to 7, characterized in that the sediment deposition is carried out by means of suction excavators or float excavators, which are preferably operated with wind energy and / or solar energy.

9. Process according to one of the claims 1 to 8, characterized in that the degraded sediment deposit is pre-ground and pre-sieved prior to further transport to the processing plant.

10. Process according to one of the claims 1 to 9, characterized in that sludge dams for conducting and sediment deposition are arranged from a flow bed or from the bottom of flowing water.

11. Process according to one of the claims 1 to 10, characterized in that the growth areas provided with the growth substrate are planted and irrigated.

12. Process according to one of the claims 1 to 11, characterized in that the growth surfaces are laterally sealed with walls.

13. Process according to one of the claims 1 to 12, characterized in that the growth areas are covered after application of the seed by means of an anti-evaporation agent, preferably with mulch-weeded structures.

14. Process according to one of the claims 1 to 13, characterized in that at least two growth surfaces are arranged in a terrace-like manner on top of one another.

15. Process according to one of the claims 1 to 14, characterized in that the irrigation of the growth surfaces is carried out by drip irrigation, preferably by underground drip irrigation, after application of the growth substrate.

16. Plant for providing agricultural and forestry-usable growth surfaces in hyperarid, arid and semi-arid deserts, characterized in that the plant comprises a sediment removal device, a first transport means, a processing plant and a second transport means, whereby the degraded sediment can be applied as a growth substrate on a growth surface.

17. Plant according to claim 16, characterized in that the first and second transport means are tubes or covered channels.

18. Plant according to claim 17, characterized in that sludge pumps are provided for transporting the sludge through the tubes.

19. Plant according to claim 16, characterized in that the first transport means is a ship or a barge.

20. Plant according to claim 16, characterized in that the sediment removal device is a suction excavator or float excavator.

Analysis of the basin, reservoir and the formation of Sediment River

The process would theoretically start by locating and analysing where the most desirable alluvial sediments are positioned in the lake, and determining the depth, composition and different levels of sediments hardness (which would later have a role in deciding upon what type of a dredging vessel to use). The sediment monitoring and tracking operation has to be done for a minimum of four (4) years (on site or via historical satellite images) – it would be important to make long-term predictions on the location and the path that the sediment river would take as it moves slowly towards the dam identifying both the most suitable location to excavate/dredge for nutrient-rich sedimented alluvial (alluvium) silt of the finest

granulation and in the same time the location which would remain a good and viable option (for a location to be classified as such, it needs to be positioned so that the inflow of sediments would be constant, and that the constructing the needed infrastructure would be cost beneficial on the long run-LCA needs to be performed) for a prolonged period of time.

Alternatively, in the case of a newly planned reservoir, there would be a purposefully designed weir dam, based on all necessary calculations to confirm the exact location of the sediment river formation based on a minimum of four years sediment tracking observations within the future dammed river, in order to determine the most suitable location for the dam, which would lead the sediment river towards the shore for further processing.

Deciding on the means of vertical sediment transport

The second step is excavating these sediments vertically, with solar- and/or wind-powered dredging boats/ships, depending on the rigidity and consistency of the excavated sediments (or 2a in the case of a newly planned lake, a fixed tube with a pump would be located at the point where the weir dam should be close enough to the processing plant, depending on the geography of the location but always being under fifty (50) meters to lower the energy needed for transport). The expected granulation (composition of dredged materials) should be of fine particles 0.2 millimetres - 0.002 millimetres in diameter, concluding that this type of dredging activity should be carried out by cutter-suction dredgers.[29] First, grinding and milling of larger particles takes place at the entrance to the dredger's suction pipe, where all larger pieces of vegetation such as branches, leaves and other organic matter get sucked in and grinded, allowing transport of more or less homogenous sediments. Instead of using traditional fossil fuels to power dredging ships is advised to use a combination of solar- and wind-powered ships. Combining wind and solar energy for maximum efficiency enabled by the geographical position of warm deserts and the weather oscillations present in the switch from night to day, causing the occurrence of noticeable daily wind patterns. The solar panels needed to fuel such operation boats/ships should be installed as a floating barge that could be pulled together with the boat or positioned across the ships" top surfaces as roof shades for crew members and to prevent excess evaporation. A wind power generator should be positioned on the same axis as the hose allowing for additional stability of the dredging boat, and in the case of a ship being used a multiple wind power generator could be installed, depending on the length of the ship.

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[29] This type of dredger has a hose that can reach depths of up to thirty to thirty-five (30-35) meters and can cut through sediments with a cutting mechanism at the suction inlet if needed, making it a reasonable option (and one which could be substituted for another depending on the location and granulation) and the composition of the sediments.

Where in a case of a ship that has two or more windmills/wind power generators, one should be directly connected to the dredger hose pump so as to not waste any energy converting the wind energy into electrical energy and then back to mechanical energy. This type of ship, equipped with both solar and wind power generators, should carry large amounts of silt to the floating pipeline, in the case of large lakes such as the Aswan High Dam Reservoir, or in case of an average reservoir, to the pipeline outpost leading to the end storage facility. If necessary, small-scale lake mining may also be used, such as a High-Lift Dredge with a booster pump powered with additional floating solar panels or an inbuilt wind power generator. Since these excavations, dredging and transport operations would be performed in desert, the effectiveness of such wind-solar ships would undoubtedly be great. The sun is at its most powerful in the desert and with the presence of water to cool down the solar panels their effectiveness would grow, helped too by the constant winds typically observed alongside the daily shifts in temperature. By using this kind of transport, we would produce a more sustainable solution with no fossil fuels being used at any point in the process and lower overall emission of greenhouse gases.

Horizontal transport

The third step is horizontal transport of the dredged materials from the dredging ship/boat to the processing plant wherein we have four different methods of horizontal basic transport:

1. by the way of a barge that accompanies the dredger,
2. by the dredger itself,
3. and by floating pipeline,
4. or some combination of these three

Whilst also taking into consideration the evaporation rates present in barges and the distance they need to travel, due to which efficiency plays a crucial role in deciding on the most suitable method.

Excavating Bottom Lake Sediments and their Transportation to the Main Processing Plant in the case of newly planned/formed artificial lake as explained above, and in the case of a newly planned reservoirs a weir dam is to be designed in such a manner that that dam would be able to redirect the flow of the future sediment river into a fixed tube/pipe laying on the shore of the lake, which would be connected directly to the main processing plant. Where the weir dam and tube/pipe meet, a pump would be located at this point, this pump would then act as a suction dredger and be in efficient pumping proximity to the processing plant, depending on the local geography of the location aiming to be always less than fifty (50) meters away from the processing plant, as in the case of newly planned lakes. This would be a single transport path from the weir dam to the processing plant at an angle to the shoreline, as the pipe/tube would be laid there. That would be why in the case of newly planned lakes it would be necessary to calculate the exact location of the sediment river formation, which would require a minimum of four (4) years sediment tracking and monitoring of the river that would be planned to be dammed, to determine the most suitable location for the dam. This would also depend on the given geographical location, and the main

factor to consider when deciding on the location would be that the dam should not be higher than two to five (2-5) meters, as this would be the first lake to be formed on the river because the weir dam would need to be located before the main dam, and the sole purpose of the weir dam would be to redirect the sediment river towards the shore where the suction tube/pipe would be planned and where it connects to the processing plant. The recommendation is *not* to plan weir dam in a way that it goes across the whole lake and blocks the river entirely, but rather, where necessary, do plan this part with two or three (2 or 3) short, smaller sequential weir dams leading the mud river onto each other.

Regardless of the chosen vessel and in all cases the dredged sediments would eventually arrive at the main processing plant.

The main processing plant

In the processing plant excavated sedimented -alluvium silt deposits- that were extracted and transported via various means, would firstly be put in an airtight room with tanks, where sediments are grinded, crushed and mixed through the mechanical force of cutters, grinders, and moulders (with the goal of making a more homogenous mixture of water and sediments with particles in the range of 0.2 millimetre - 0.002 millimetre). This would be followed by a specially designed closed chamber with a rotation platform for settling. Here the speed of settling would be measured with optical sensors, which would allow defining the composition of the particles present in the mixture. After settling, more sensory testing should be performed to calculate the exact amount of clay[30] present in the mixture, later on sediments are mixed in the ratio 40:60 with a satisfactory level of clay being not higher than 20 % of the overall dry residue, or up to 20:80, if the clay content would be higher. The most important part in this step would be to monitor and note the formation of non-Newtonian fluids. If this is miscalculated it could lead to explosions in the pipeline under extreme desert weather conditions. In the last steps happening in the processing plant, the mixture of alluvial silt would undergo a final grinding and mixing process if needed, in which water content would be added or reduced based on the calculations performed in the previous step and in relation to the clay content; from here sediments would be pumped into the main pipeline and distributed further, onto the chosen location. Depending on the location of the next pipeline and the velocity of the flow required to pump the mixture different sized pumps would be used.

The main pipeline and planning of its route

After the mixing ration has been determined by advanced analytic algorithms and sensors, the mix would be pumped into a purpose-built pipeline, the main pipeline, which would make its way through the desert. For this operation it would be desirable to use already available infrastructure, especially with small dams, as

[30] Clay is the main factor in development of non-Newtonian fluids in turbulent pipeline flows.

the sediment river in those cases would always be close to the dam itself, and the entire system described would be located closer to the dam. In this thesis the focus is on the Aswan High Dam reservoir and its sedimentation, for this specific case there would be an abundance of already available infrastructure, which is full length described in Toshka Project review, hence worth mentioning that in this case the Sheikh Zayed Canal would be used to lay the pipelines. Meaning that the inland pipelines (made of high density polyethylene (HDPE) which has pressure ratings of up to 1.1 MPa) can follow the existing infrastructure used previously to construct the dam.[31]

When planning the route for the main pipeline the geography of the region and the geology of the desert - what type of desert it is, sand, stone, or a mix, how hard the ground is, how permeable and porous - always needs to be taken into consideration while also taking into account the existence of present nearby oases. *In order to plan for creating the green connection between these oases, as the presence of underground water would be then secured, once the path would be chosen and the main pipeline would be laid therein.*

Designing the Main Pipelines Pathway (made HDPE) which has pressure ratings of up to 1.1 MPa), based on the location chosen to use as the most suitable path in relation to overall CO2 emission would be gained from performing a full Life Cycle Analysis (LCA) on each separate reservoir. In other cases, the free fall such as natural decline of the land or similar, should be utilised as much as possible. Valves would be installed every one thousand (1000) meters for monitoring, security and cleaning purposes. Important for all pipeline designs are the fluid mechanics of the designs. Ways of overcoming inclines or potentially gaining more energy for continuing the transport can be found in some basic rules of physics, and application of these rules in their entirety requires demanding careful and calculated planning in order to:

- Rapidly lower the pipe's height
- Reduce the pipe's diameter directly in front of the turbine
- Dig tunnels to overcome higher inclines or for other purposes

The Main Pipeline would be in accordance with calculation of the lowest overall level of CO2 emission gained from performing a full Life Cycle Analysis (LCA) on each separate project, and that this would also influence the geographic

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[31] *In* special cases, such as the case of the Aswan High Dam Reservoir, when the lake is very long and the distance between the sediment river and the dam is large, the best would be to use available infrastructure, as mentioned above, in a case of AHDR the Sheikh Zayed canal could be a path wherein the inland pipelines are laid. The Sheikh Zayed canal was made impermeable to prevent seepage, so the pipeline carrying construction would have to come from the top and close the canal with a roof-like surface made of solar panels that would at the same time prevent the huge evaporation rates typically present in the Tropic of Cancer.

orientation of the pipeline. There would be areas where the most suitable and cheapest way to construct the pipeline would be to dig the pipeline into the ground surface, such as in areas where unstable or sandy soils and/or dunes are present. There would be areas where the most suitable and cheapest way would be to have the pipeline above the ground surface, such as in areas where hard rocky deserts and/or granite stones surfaces are present. The Main pipeline would be equipped with that Robotic Cleaners should be used to clean the pipelines. The Robotic Cleaners should consist of a metal ball structure connected to form a semi rigid line that at its back end has a motor and propeller which enable it to travel through the pipes and on the front end has a pointed concave head from which brushes and whiskers, with sequential wheels, would come out in a circular motion and extend to the exact inner diameter of the pipeline. These robotic devices would travel from one valve to the next and clean the pipelines.

The next step is planning for a further subdividing of the main pipeline into smaller pipelines that lead to individual fields, branching out. Branching depends on the area and whether the fields are located on hilly rock with a firmer surface, a sandy-rock hilly surface, or on a flat sand or rock surface, each of which would require a different approach to designing the final look of the irrigation on the fields and preserving the sediments from leaking out, hence informing the branching direction and final outlook of how pipes would be lied down.

The Transition from the Main Pipeline to the Sub-Pipeline which would bring the mixture to the fields being irrigated can be done, depending on the sediments available in the particular lake and the power of the processing plant, over a maximum of seven (7) kilometres in length on each side of the main pipeline and with a minimum of one (1) kilometre in length on the main pipeline from one partition to the next. The same principle should be applied in any bifurcation of the main and sub-pipelines further into the project and the fields.

Once on the field, irrigation would vary widely from the terrace to drip irrigation with sediments, depending on the geomorphology of the terrain. Depending on the geographical area of the location chosen for the agroforestry system it would have Different Irrigation Approaches, and in the case of hilly deserts with firm solid soil surfaces (and thus predominantly rocky or hard dirt surfaces), a terrace system should be applied for irrigation, meaning that the field should be fenced with at least twenty to twenty-five (20-25) centimetres of elevated stone-dirt walls and the surface of the field flattened so that the newly incoming sediment-water mixture can settle equally in the field and leave it with the enhanced possibility of producing fertile soil.

Or in the case of a hilly deserts with semi-firm or semisolid soil surfaces (and thus predominantly sandstone or hard dirt surfaces), a Terrace System as described above used for fencing with at least twenty to twenty-five (20-25) centimetres of elevated stone-dirt walls and the surface of the field flattened so that the newly incoming sediment-water mixture can settle equally in the field and leave it with the possibility of producing fertile land enhanced, while also leaving a hole at the bottom for the field to decant and follow on to the next lower level fields, thus irrigating the next field by overflowing or decanting into it. If available, seedlings should be planted immediately and covered with available organic material on top

of the newly irrigated field, such as leaves, mulch-weeded structures and other similar matter.

While in the case of sand dunes or of flat, sandy deserts with sand mass as the predominant soil surfaces, first the boundaries of the field should be determined and the appearance of constant winds and their power gauged. Second sand stabilisation needs to be taken into account depending on the available resources, both material and financial; this step can take on many forms, and only afterward focus on irrigation system. After this has been done one of either two approaches would be applied for field protection from windblown sands: Robotic Fencing or Native Shrub Species Fencing. Herein is described the method of Native Shrub Species Fencing: to establish the thick vegetation of a shrubby fence, native species should be used, with a first defence layer of cacti, then trees such as Acacias, Fake Acacias and Black Locusts, which are fast growing and native to the desert, are planted, after which shrubby trees from the Moringa family should be planted, or other available fast-growing shrubby species native to the desert (as they do not require great amounts of irrigation). After six (6) months regular planting, sub-surface drip irrigation of the agroforestry system can be started. If available, seedlings should be planted immediately after this period of six (6) months and covered with available organic material on top of the newly irrigated field, such as leaves, mulch-weeded structures and other similar matter.

Continued irrigation in all mentioned cases of field irrigation, should be done through sub-surface drip irrigation.

After the irrigation method had been determined, the fields would start to be irrigated with a special mixture mud and water coming from the reservoir.

In certain cases, this part will depend on the way chosen by them.

If the winds are very strong for the first period of five to ten (5-10) years, depending on the particular system and species chosen for plantation, provision for a solar-powered robotic shield would be made; a simple fence-like structure formed firstly of wind-powered turbines to slow the wind and then of solar panels that would work as a shield to protect the fields. These specially designed solar panels would be semi-transparent, robotic and coated with a layer that protects them from any damage caused by catching excess water evaporation. Wind turbines and solar panels would be used primarily as the first line of defence against the harsh desert winds. Solar panels would provide a triple line of protection.

First, they would be used as sand blockers, acting as shields programmed to react when a sandstorm would be approaching, with algorithms that receive signals from nearby weather stations and onsite sensors that register the change in intensity of winds, and rearrange the solar panels into a protective formation while keeping the hard-earned soil from turning back into sand. Secondly, the solar panels should be used as sun protection, being semi-transparent and made so as to be adjustable to sun and absorb as much of the Sun’s energy as possible when it would beat its highest point while allowing the plants to also use it when its rays are weaker, in this way protecting the plants from frying in the desert sun before the stronger

desert-thriving species are fully established, but still allowing them to use the Sun for photosynthesis. The solar panels" third use would be to collect evaporation using their specially designed water-resistant rear surface, allowing us to reuse this water for irrigation purposes. They would also provide the newly established village of the 21st century with the electrical power it needs. If available, seedlings should be planted immediately after this robotic system would be established and covered with available organic material on top of the newly irrigated field, such as leaves, mulch-weeded structures and other similar matter. Continued irrigation of the field should be done through sub-surface drip irrigation.

The agroforestry system

This agroforestry afforestation approach for hyperarid deserts would be able to develop and grow new soil which makes this a beyond sustainable approach for desert greening.

The first irrigation with our mixture would make new soil and provide the land with nourishment needed to develop the agroforestry system. With careful maintenance and planned growth, managed through intense education of the local population that would work these fields and a hands-on approach for at least five (5) years (such involvement would also allow for a period of sixty (60) years of monitoring for carbon credits and in line with the United Nations definition of afforestation implementation of this methodology would be able to leave the forest in a position where it would grow without any human help, in irrigation or similar, this approach could have a great influence on global climate, not just by relying on afforestation but by using the system described here which cleans reservoirs to speed up the process of afforestation and thus influences microclimate at the right location and for the right amount of time to trigger a change in the global climate, if the project ultimately developed would be large enough. The benefits of using this kind of process would be far-reaching since it would not only provide savings in water and another use for dredged materials, but create a new, sustainable way to reclaim drylands and desert lands.

Fields would be planted with an appropriate combination of indigenous desert, semi-desert and Mediterranean plants in accordance to an agroforestry system design. With an aim of fixing nitrogen levels with the first harvest, the carrier crop or the tree species used has to be a tree from the local nitrogen-fixing trees (explained in detail in agroforestry chapter) or the Moringa family (in the case of the Egyptian Sahara this would be Moringa Peregrina), and this kind of system would enable us to preserve this highly valuable soil, develop and grow forests that aside from storing carbon dioxide are able to feed the local population, grow more soil, thus making implementation of this patent an example of sustainable afforestation in hyperarid deserts.

This Unique Agroforestry Approach is capable of utilising the desert conditions in the most productive manner. By looking at the table, Figure 74., a clearer image can be gained on the scale of the conventional conservational agricultural approach. The Food and Agricultural Organisation Save and Grow approach would be the closest to conventional agriculture while "Biodynamic" would be the

furthest away from this, but unfortunately also the furthest away from a classical scientific approach.

Taking the most important elements for sustained desert conditions, from each of these approaches, the conservation agricultural approach to greening deserts successfully, described in this thesis, is based upon all of the above approaches and other recognised desert greening approaches, which have been developed into a single unified approach best suited to desert conditions and are employed in combination with the transportation system for desilting lakes.

Viewed from the Agroecological point of view, the approach developed in this thesis, is actually a system for observing the approaches and measuring and counting their validity. Agroecology which would allow future adaptations and changes and a clear scientific approach based on measurable data, and proven, successful practices and policies. Some characteristics of older approaches that were adopted in many different approaches were also included as they have become widely adopted, such as Keyline Design, Polyculture, and Clay Seed Balls. The same cannot be said of genetically modified organisms, which have become widely unaccepted and the available data coming from independent sources is not sufficient to draw any conclusion on their direct use in free ecosystems, the decision has been made to exclude them entirely until further research becomes more available.

The approach developed in this thesis as a derivative of multiple conservational approaches.

While keeping the key principles of care for people at the forefront, the environment and economic feasibility, this approach is the most similar to Ecoagriculture and Permaculture, and has Agroforestry as a key field of profit so that the majority of the land that would be turned into forests governed by the rules of Ecoagriculture and Permaculture, while obeying the rules of International Federation of Organic Agriculture Movements (IFOAM). Registering all produce harvested in line with the strict rules of the IFOAM, as organic, considering that IFOAM has already set very clear and concise rules for farmers to follow. But while some might develop in other directions, the belief here is that it would be of utmost importance to register as an organic producer if one belongs to any of these agricultural approaches, as organic know-how represents a solid base from which to start building healthy and sustainable agricultural systems for the future with higher profit margins for each organic producer. The focus on a no-till system should be accentuated as in desert conditions the actual building of the soil is crucial for the project's progress - keeping the permanent organic soil cover throughout the year would not only add to the increase of the soil's organic matter but also effectively prevent increased rates of evaporation present in the desert. Biodiversity enhancement would be present through using the Permacultural Approach to planting diverse species, with a tendency toward always using local and highly adapted varieties with high yields and a high tolerance for drought, while planting them in no less than seven (7) layers of forest.

Included in this approach would be animal husbandry and Allan Savory's Holistic Management System for grazing cattle, again using species that are native or

already adapted to high levels of droughts; Polyculture and Companion Planting are also integral parts of this approach as these separate approaches have become so widely accepted that their characteristics have been included even though they are considered separate approaches. Keyline Design would be used not so much to harvest rainwater but rather to retain the excess water from irrigation, and would be used in conjunction with Holzer Hügelkultur beds made of available wood material, should the location be able to provide this material. If no such material would be available, this function would be filled by newly trimmed branches of Moringa genus trees, as their trimming would help sprout the life in their roots with bacterial and beneficial microorganisms.

In order to be productive in the desert there would be no space for waste as every single part of the plants and animals must be used to enhance the soil's organic content. In this context of enriching the soil with clay, when widely available, and in these locations the use of Clay Seed Balls is encouraged, as a higher clay content in soil has been proven to increase soil fertility, especially in deserts, making soil more drought resistant and able to withhold water. Taking on board the conservational approach some of the system's characteristics are based on the Food and Agriculture Organization's Save and Grow approach as it contains three points which are quite appropriate for the present system.

1) Using the high yielding varieties from a good seed stock would enable initial sprouting, but farmers would be encouraged to preserve their own seeds and to use their own varieties (while also possessing the knowledge and the ability to use the foreign seed stock).
2) An integrated pest management system present as in Permaculture (as well being an important factor in the "no-chemicals" method).
3) A planning nutrient addition based on soil that has been previously tested, so as to know which additives are actually needed and which plants can provide them. In the alley cropping parts of the agroforestry system, as well as in all the newly produced grassland available, the crop-pasture system would be encouraged, as each practice adopted in this complex should not serve a single purpose alone, but form multipurpose parts of a very simple approach that strives to be self-sustained in 100 years" time, regreening the desert in the process.

In any afforestation project that aims to be defined as successful, "sustainable" means becoming self-sufficient. It has to not rely on human interference. Meaning that constructing Systems that Grow Soil and grow out of the necessity for irrigation by creating a microclimate suitable for maintaining the life in the soil and in the afforested land is the aim. Here a way that uses education to achieve this is proposed, by engaging the local population with the trees planted and teaching them through hands-on methods how to manage a successful agroforestry system from seeds and seedlings to full development. This would include imparting knowledge on which plants should be planted together and how this should be done. The project would also employ a hands-on knowledge approach to integrating the local population into the life of the project and the agroforestry system, teaching them the benefits of non-timber forest produce and inter-cropping in the desert.

Conclusions

A summary of findings

This thesis has so far produced a novel patented methodology for desert greening. This methodology's uniqueness and strengths lie in the fact that it was created out of necessity and not out of commodity - it was created as a means to restore the natural flow of water, sediments and nutrients in a dammed ecosystem, based on an extensive literature review and a theoretical example of the Aswan High Dam Reservoir in Egypt and its nearly 7 billion tons of sediment.

Starting always from a point of restoring the natural balance, which has been disturbed by the creation of a dam, it is proposing restoration by focusing on utilising of sediments (excesses, unwanted material) from behind the dam and giving it a second life, a purpose and meaning in revitalizing the natural flow. Using biomimicry as an inspiration this methodology uses locked sediments in creation and restoration of surrounding landscapes, by using sediments as building blocks of topsoil in the hyper arid, arid and semi-arid environments, with extended application to any other ecosystem suffering from land degradation in a vicinity of a dam and its reservoir.

The importance of this methodology stands out in utilisation of otherwise unwanted materials, especially giving focus and priority to the part of sediment accumulation which is silt. In most riverine ecosystems alluvium soil that has been created and brought by the river throughout the ages pilling up at the delta, is usually making it one of the most nutrient rich topsoils in the world.

Creating such a methodology able to revitalize once lotic ecosystem, from lentic back to lotic – as silt is being transported via pipelines to be used as topsoil in nearby environments is a step in the right direction of revitalizing the planets resources to meet the needs of the predicated population growth in the face of climate change.

One of the most important pieces of the puzzle which came after the literature review and further research had been done was that there is no centralised data system integrating the freshwater availably of the world's dams. Furthermore, there is no centralised system mapping out all dams of the world, we only have International Commission on Large Dams or ICOLD which maps and monitors the large dam structures, while many medium and small dams, which are by default more prone to sedimentation, stay unnoticed and more importantly neglected, causing devastating problems for local populations and creating fake security for local authorities. I was privileged to spend a summer of 2017 at NASA Ames, where Dr Ramakrishna Nemani, from NASA Ames Ecocast division, is heading a new research group focused on using satellite images to map the small and medium dams across the world, to a get better understanding of the importance of this issue for the future of water security and water related safety. Special challenge in creating such a comprehensive dataset and integrating it with available local governmental datasets is located in the developing world, this is where the structures themselves are also the most endangered and pose a greater risk as in

many cases their maintenance and good up keeping is not the first priority of the local government.

A most obvious and certainly most important piece missing for me is something that I am now actively focused on, involves mapping the world sedimentation accumulation in the reservoirs. A comprehensive dataset allowing us to see at any given moment what is the current sediment accumulation, proportion wise, percentage wise and also composition for global reservoirs (natural lakes in the future too) and individually for each system. This type of a system would allow for an easy and guided decision making in regards of implementing the methodology developed in this PhD thesis as well as restoring the natural ecosystem. An important tool any government needs to have access to.

Already now just by observing the common news channels one can see the importance of the freshwater availability to any given country or a local province, this is exasperated by the overwhelming facts of the current state of the climate change and our available freshwater resources. If one digs deeper into the literature it becomes obvious of what great importance the freshwater availability and the ability to predict this accurately, will present in the near future.

Ultimately this thesis has produced a patent for a methodology for desert greening, now recognised and accredited by the United Nations Convention to Combat Desertification UNCCD.

Limitations of this thesis

A summary of limitations

The biggest challenge of this work was acquiring a complete dataset on global sedimentation rates. There is no such dataset addressing the water to sedimentation ratio globally present in reservoirs, therefore it was not possible to take an overall approach and look at the world's reservoirs, with their available storage and future predictions of it. There are numerous platforms assessing the freshwater availability, but none is measuring the sedimentation, although they are all acknowledging that sedimentation is one of the most limiting factors of their freshwater prediction models. One of the reasons why this research work was limited to the Aswan High Dam Reservoir was the availability and access to the clear, official and open source datasets on the sedimentation of Aswan High Dam Reservoir. This together with different assumptions regarding the prediction model, and that in regards to where and when in the future the reservoir will be sedimented made Aswan High Dam Reservoir an easy choice.

Predominantly in this work I have relied on the UN datasets, mostly using Aquastat of FAO UN, FAO, IPCC, ICARDA, IADC, ICOLD and on the IFOAM dataset. Meaning that for the dams and sedimentation accumulation this work has relied on the dataset provided by the ICOLD and IADC, which is by no means enough to draw conclusions on small and medium dams at this point, only assumptions.

Other limiting factors were that governments and other dam owners" use and relay on very localised systems for measuring and monitoring sedimentation rates, and are usually not shared amongst each other nor with/via any online available data system.

There is no centralised dataset for global sedimentation rates, like there is for many other of the world's critical issues. Sedimentation is predicted by ICOLD, to take more than 42 % of world's reservoirs volume by 2050. However, these assumptions were made without a central system which would contain the measurements of medium and small reservoirs. How can we predict something as valuable and as important for humanity as the availably of the freshwater that is in its volumes directly correlating with the volume of sedimentation globally, when we do not even have the accurate numbers of small and medium dams that are supposed to store the freshwater for us?

The limitations of these datasets

ICOLD dataset takes into account only the large dam reservoirs and offers the sedimentation for those whose governments allow further publication. It was fine for focusing on the Aswan High Dam Reservoir however it does not help in with researching smaller dams in the surroundings nor any other dams but large dams.

UN Aquastat dataset is mostly limited to all different freshwater sources, where and how it is used and located, but does not have a sufficiently developed dataset on sedimentation within the reservoirs.

ICARDA- International Center for Agricultural Research in the Dry Areas, used for the agroforestry part of this thesis as well as the patent application, is a reliable dataset for many different plant species and methodologies used in dry regions to produce food. I was privileged enough to meet one of the former directors of ICARDA at the Eurosoil congress in Istanbul 2016 where I presented this thesis and got an overwhelming response from fellow researches.

Further limitations of this research

This thesis is based on literature review, theory and a patented system design for methodology on desert greening. It would have been great if I had sufficient funds to implement a small pilot project and follow its growth. Unfortunately, due to the timeline of such a project of at least 10 years and a budget of at least 5$M for a 1km of pipeline the idea of pursuing such a plan was abandoned earlier in my work and it was limited to extensive research and interpretation of their outcomes, with the only pilot being done on a very small scale 100 Moringa Oleifera plants during the summer spent in NASA Ames California- a semi-arid location.

The core questions of this thesis

This research revolved around three core questions:

1) Can we bring back to the Nature what is rightfully hers? In the meaning of sediments and silt locked behind the dams.
2) Can we reverse climate change, by utilising sediments accumulated behind the dams as an ecosystem kick starter for new afforestation projects in arid and semi-arid lands?
3) Is agroforestry the way and the solution for afforestation in the drylands?

First question of “Can we bring back to the nature what is rightfully hers?” is questioning if we can recirculate the silt and the sediments back into the natural ecosystem, as it used to be flowing for thousands of years, before humans started making dams, and if so, what would be the least destructive and the least harmful way in doing so.

Specifically targeting the Aswan High Dam Reservoir, this research looked into all different proposals that were active around the AHDR and its surroundings, those that took place and those which stayed at the proposal level. There was no project addressing the growing accumulation of sediments in most of the Ethiopian part of the AHDE and all the way up to the vicinity of the Mubarak Pumping station and the general Toshka region. The Toshka lakes, which were created as a safety net for protecting the population below the AHD from flooding, were by no means predicted to take on the sediments or to address them in any way. Also the Toshka project of regreening this area of the Egyptian desert, which had started more than a decade ago, did not bear any fruit in regards to desert greening. I am of the opinion that one of the main political reasons for these failures lay mostly as a result of not integrating the sediments into their projects. Different options of reintegration of sediments were considered, starting from ship transport, inland transport via trucks and via rail, to ultimately deciding to go for the pipeline system as the most sustainable, easily assembled/dissembled and reusable mode of sediment transport.

Dam removal as a means of permanently restoring the order of things was considered, however due to the importance of the AHDR to the Egypt and its people it was easily discarded as impossible. However, as a recommendation it should always be considered for small and medium dams.

As the final outcome of this work, a pipeline system that would transport approximately 7 billion tons of sediments was envisioned with power stations and buster pumping stations to transport the sediment from the Mubarak Pumping station all the way to the Faiyum Oasis and Cairo, following the natural oasis that occur along the way, connecting one by one along the way. This design and later on use and treatment of the sediments, has produced a patent for an entirely novel methodology in desert greening, opening doors for this type of greening method to be deployed across the world.

If dam and reservoir maintenance can have as a by-product a cheap and fast desert greening patch, this opened the door to a second question of this thesis: “Can we reverse climate change, by utilising sediments accumulated behind the dams as an ecosystem kick starter for new afforestation projects in arid and semi-arid lands?” Based on some previous work done by afforestation pioneers, like Prof Hani El Kateb in Egypt, I looked into three possible scenarios in the case of having access to all of the 7 billion tons of sediments in the AHDR All three scenarios were based on the minimum carbon sequestration calculations of only 1 ton of carbon dioxide per year, and the life of the afforestation project (the life of the newly planted forest) was taken to be 60 years.

The first scenario was based in needing 20 cm of sediment on top of the sand to kick start the system, which we already know would be too much based on the

topsoil thickness in the drylands, this would produce the forest the size of Styria, a small region in Austria, 1.6 million hectares, and would be able to sink 99 million tons of carbon from the atmosphere, or what Austria emits per year.

In the second scenario, the assumption was that to kick start an agroforestry ecosystem one would need 10 cm of sediment on top of sand. For this calculation we got an area the size of Estonia, 3.2 million hectares of agroforestry land. This agroforestry system would be able to sink 399 million tons of carbon or what France emits per year. And in the best-case scenario using the 5 cm of sediment, considering this to be enough to kick start an ecosystem, we get a forest the size of Latvia, 6.4 million hectares. This huge surface area would double the Egypt's agricultural lands and be able to sink 1.19 billion tons of carbon or what Russia emits per year.

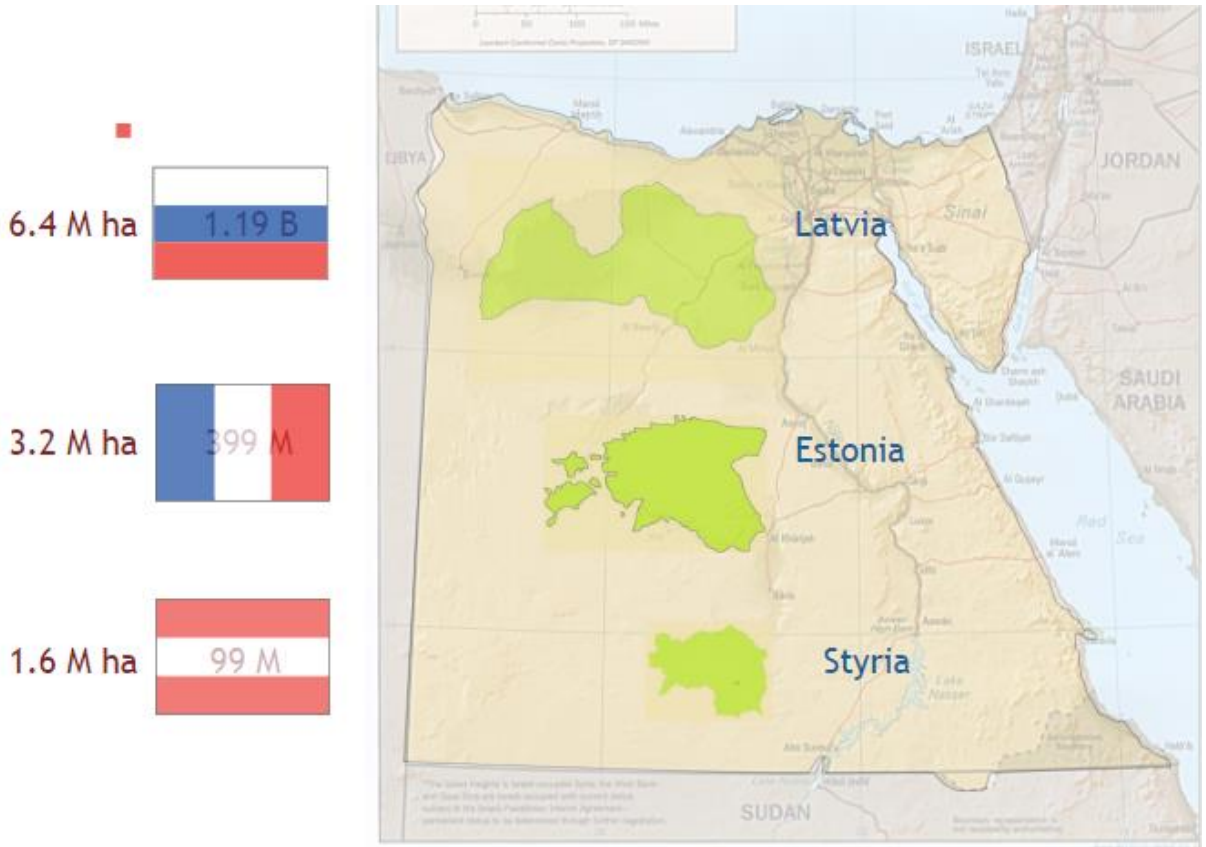

Figure 82. Maps of Latvia, Estonia and Styria superimposed on map of Egypt. (Author)

If we take the best case scenario as the most feasible and realistic one, as 5 cm to kick start the ecosystem, which is approximately what we measure as the worlds" topsoils, and apply the same principles to other endangered reservoirs or dams in the arid and semi-arid region we could hypothesise that this type of mandatory dam maintenance would be enough to sink the historical carbon emissions approximately 550 GtC with 460 projects like AHDR, knowing that we have millions of small and medium dams across the world that would benefit from such a maintenance it would be reasonable to consider that the outcome of reversing the climate change with this methodology is plausible.

However, as we yet do not have the exact GIS locations of many medium and small dams, nor do we have a centralised dataset that monitors all dams, we do not have any means to even assume the volume of sediments globally and this hence leaves many of the assumptions only at this stage of assumptions. Creating a computer model able to compute the world climate while taking into consideration all the important factors that would need to be factored in for ecosystem restoration is too many unknown variables for current systems, and as their accuracy dwindles the more zoomed out a model becomes so does their reliance, hence modelling of a such a hypothetical outcome via IPCC or any other climate modelling tools was not considered at this stage.

Therefore, we currently have assumption only that implementing this methodology as mandatory dam maintenance would reverse climate changes to pre-industrial levels.

These lingering thoughts that cannot be confirmed nor disproved for many years led to the third research question "Is agroforestry the way and the solution for afforestation in the drylands?"

In most of the drylands, reaching soil degradation neutrality is a great challenge, now taken on even by the UNCCD as their prime mission, a challenge best addressed by stabilising the soils with agroforestry. Why?

Over population as a term has been primarily used by many of the leading UN bodies, however it is not accurate to say the world will be over populated or that we are already over populating our planet, a more accurate term would be that we are not inhabiting the planet in a way which allows for a stable and sustained growth of population.

MENA region is the most at risk region at failing to sustain its predicted population growth, as it is the fastest growing region on the planet, with little to no arable land, highest desertification rates, land being lost to the cities – urbanisation due to fast growing population, land being lost to land degradation, soil depletion, soil salinization and many other factors amongst lack of readily available fresh water is what is making the region not suitable to sustain the population growth it is expecting. These and many other factors are leading local rural population to migrate to the city, exasperating the urbanisation and contributing the growing problem of urban sprawl omnipresent in the region, further on many of the people are forced to become migrants and sick refuge on their way to greener pastures – aka Europe, which is in return creating stricter and stricter laws and having a wave of right wing governments across EU as an answer to the growing migration crisis, none looking at the rout of the problem – which has always been the substance of life anywhere on the planet.

Agroforestry, done in a way that has been described in this work, as a Polyculture food forest which utilises the silt as an ecosystem kick starter and relies on the local and lucrative plants suited for drylands, is exactly that, in an essence it provides the urgent need for food year round, as it is not based on monoculture, it creates jobs, creates and preserves the arable land, generating new topsoil and liberating the farmers family from debt and over exploiting of big agribusiness and

dead aid from developed countries, allowing for a decent living and a contribution to the fight of reversing the climate change.

This leads to the conclusion that even if reversing the climate change to pre-industrial levels does not work out, this methodology will be of use to the countries which are the most affected by the climate change and these are developing countries in semi-arid and arid regions such as Egypt.

Building topsoil by maintaining dams and reservoirs, with no harmful effects to the environment, by using agroforestry to preserver the newly placed soil and generate jobs, food and stability are just some of the reasons why agroforestry has been adopted as the way of farming in drylands by UNCCD and FAO UN.

Further research and work recommendations

What we need to know in order to utilise and implement the full potential of this work:

1) How much silt – sediment accumulation there is in the world's reservoirs
2) Integrate sedimentation accumulation datasets amongst countries
3) Actual number of dams world wide – ICARDA only accounting for large dams, not medium and small ones

Datasets some of the work already taken on by various organisations, associations and intergovernmental bodies: - Afforest for Future work and partnerships

1) NASA Ames mapping out world's small and medium dams
2) Using satellite images to map out dams
3) Use satellite images to map sedimentation
4) Computer vision AI to predict the movement and accumulation of sediments World Wide
5) Which leads to an accurate freshwater monitoring platform
6) Observing ground water levels and salinity correlation with satellite images
7) Integrated approach to agroforestry by prolonging the dam life

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Curriculum Vitae:

Architectural engineer by profession specialized in zero emission buildings, with a focus on waste water treatment through living machines with no chemicals used. She has transferred this knowledge through doctoral research into a sustainable transportation system for greening warm deserts across the world and for large scale afforestations in geoengineering efforts towards a safer world. An energetic, talented, self-motivated young scientist driven by her vision of a green Sahara, eager to help people mitigate the effects of climate change with a strong desire to build a career via implementing knowledge gained during her PhD studies. Massively efficient and methodologically sound with highly developed scientific researching and writing skills.
Vesela is at present looking for suitable partners to join her in her quest to green the world's deserts. They should be active in at least one of the fields involving sustainable businesses, social entrepreneurship, preserving the environment and helping to mitigate the effects of climate change.
She has excellent collegial skills; extensive experience working in international teams; and is highly proficient in English.

Professional Experience and Projects

Afforest4Future	***Founder*** *March 2016 – Present* • Transforming deserts into food forests via patented afforestation methodology developed at TU Wien.
Technical University of Vienna (1040 Vienna, Austria)	***Researcher*** *March 2012 – Present* • Fields of interest: Afforestation of the Sahara Desert; Forestry; Agroforestry Systems; Ecoscaping; Water Management; Wastewater Management; Sustainable Irrigation
REA/C/04, Research Executive Agency, European Commission (1049 Brussels, Belgium)	***External Expert*** *May 2015 – Present* • Evaluator of Horizon 2020 projects proposals - Fields: Water; Wastewater; Water Management

Gramont Inzenjering (18000 Nis, Serbia)	***Research Architect*** *July 2012 – Present* • Remodelling of EKO-Gramont wastewater facility; system design; sustainable use of water; water management; Irrigation ***Architect*** *January 2011 – June 2012* • Supervision of construction sites; Project Management; Remodelling of EKO-Gramont wastewater facility
Building Projekt (18000 Nis, Serbia)	***Assistant Architect*** *January 2009 – December 2010* • Construction site monitoring; Assisting in project management; Architectural project drawing using relevant computer programs

Education

Technical University of Vienna, Austria	***PhD Candidate*** *March 2012 – Present* • Faculty of Architecture and Spatial Planning, Institute for Transportation System Planning Title of Doctorate Research: *Making the Sahara Desert Green. Sustainable Transport Design for producing new Agricultural Land from Desert*
University of Nis, Serbia	***Diploma Engineer of Architecture*** *October 2004 - December 2010* • Faculty of Civil Engineering and Architecture Title of Diploma Work: *Zero CO2 Hollywood Mansion*

Languages

- Serbo-Croatian: Native
- English: Highly proficient (IELTS academic)
- Russian: Very Good
- German: Good (A2)
- Italian: Good (A2)

Other Skills

- Scientific writing
- Team leadership
- Project management

Interests

- Afforestation
- Green buildings
- Water management
- Ecoscaping
- Environment
- Climate change

Other Studies/Awards

- Keynote, opening talk at the NASA Space Apps Vienna Space (2018)
- Judge at CLIX, World Future Energy Summit Abu Dhabi, UAE (2018)
- Alumna Dubai Future Accelerators part of Dubai Future Foundation Dubai, UAE (2017)
- Vesela's newest research topic "How do we make Sustainability Exponential?" was presented through a series of lectures, hosted at NASA Ames headquarters CA, USA to two delegations from WKO Austria, and she continues to be actively promoting and researching this question. (2017)
- Part of SU Ventures Companies(2017)
- Attended SU Ventures Incubator, at NASA Ames Research Center(2017)
- Alumna Global Solutions Program 2017 Singularity University NASA Ames Research Center (2017)
- Talk at the NASA Space Apps Vienna Space (2017)
- Accepted into Climate-KIC accelerator (2016)
- Participant at the Living Blue University (2016)
- Silver status winner of the European ClimateLaunchpad Finals 2016
- Access to INiTS Startup Camp (2016)
- Winner of the Austrian National Finals of ClimateLaunchpad 2016
- Holder of scholarship dedicated to PhD students from the Technical University of Vienna to delegates at 5th International Eurosoil Congress in Istanbul (2016)
- Presenter at Vienna Young Scientists Symposium, presenting my research 'Making the Sahara Desert Green. Sustainable Transport Design for producing new Agricultural Land from Desert', presentation and poster (2015)
- Founder of the ExYU Brainiacs group on LinkedIn, which gathers together brilliant minds from the ex-Yugoslavian countries whom have emigrated, are now central members of their respective academic communities, and whom are willing to engage in research and non-governmental work for the benefit of the Balkans as a whole (2015)
- Horizon 2020 project development and proposal writing (2015)
- Certificate 'Presenting your research - Making efficient presentations in English', awarded by Norris and Steiner in cooperation with TU Wien and Genderfair (2014)
- RCE Vienna/INEX/OeAD scholarship holder and participant in international summer university Green.Building.Solutions. (2013)
- Full scholarship from Gramont Inzenjering (2012)

References available upon request