Forestry Department

Food and Agriculture Organization of the United Nations

Serapium Forest Plantation, Ismailia, Egypt:

Forest Management Plan 2013-2022




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Foreword

Globally, Egypt is one of the countries with the lowest forest cover (70,000 ha and %). The few natural forests in Egypt are made up of mangroves that can be found along the Red Sea. Almost all of the planted forests have been established on marginal lands and irrigated with treated waste water. In Egypt forest plantations support the thriving of agricultural crops, thus enhancing food security, and are an important means to store carbon in the soil and plant tissue and combat desertification trends. Despite their importance for the agricultural sector, the country is still lacking in forestry expertise and silvicultural knowledge which are key to ensure sustainable and effective forest management, including reforestation and afforestation activities.

With an average rainfall of 100 mm maximum per year and strong evapotranspiration rates, the real limiting factor to forest development in Egypt is the availability of water. As most of the plantations are irrigated by treated wastewater, as in the case of the Serapium forest, the availability of water is not really a concern but instead the reliability of water supply through water pumping systems the proper functioning of which can affect forest survival.

This forest management plan will support the Egyptian Undersecretariat for Afforestation in analyzing and evaluating the work carried out since the establishment of the Serapium plantation in 1998. It also provides advice on how to improve wood quality, integrate local stakeholders in the establishment of forest product value-chains and to take advantage of new market opportunities.

The forest management plan also represents a commendable example of country capacity building and of team work, since it materialized only through the committed involvement of FAO forestry experts with professionals of the major forestry institutions in Egypt. A great deal is still to be accomplished in the field of forestry training and to raise awareness of best management practices in forestry and agroforestry linked with water management.

We hope that the forest management plan of the Serapium plantation will serve as a model to be replicated in other forest plantations in Egypt. We also propose the establishment of an education center in the Serapium Plantation, to be used as a training center for technicians and experts in the field of forest inventory and data collection in order to support the government of Egypt in strengthening and improving its capacity and capability to achieve its environmental and developmental goals.

Alberto Del Lungo
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Summary

Egypt has limited forest management experience. This prompted the government to ask for the support of FAO to develop a forest management plan for the Ismailia Serapium plantation for capacity building purposes.

In the framework of the project '*Forest restoration in Algeria, Egypt, Morocco and Tunisia using treated wastewater to sustain smallholders' and farmers' livelihoods'* (GCP/RAB/013/ITA) a team of FAO forestry experts developed a forest management plan for the Ismailia Serapium plantation in cooperation with national project institutions . This document presents the results of the mission and training provided, suggests recommendations for further improvement of the plantation conditions and it also provides a chance to reflect on the status quo of the forestry sector in Egypt and on future opportunities for its development. The plan is intended for national forestry experts and decision-makers. It is also of use for those concerned at various levels within the Egyptian forestry sector and it can be of interest for those who want to know more on the use of treated waste water for irrigation and development purposes.

Chapter 1 describes the framework for the developed management plan and the objectives for Serapium forest are described. The objectives are to produce wood by using treated waste water in a most effective way. This prevents further pollution of ecosystems and contributes to supply local markets with woody resources. Social, ecological and economical sustainability shall be achieved by carrying out the activities at the plantation.

Chapter 2 analyses the current situation at the plantation. It explains the method and the results of the forest inventory, realized during the "Integrated Forest Inventory Training" in September 2012. The current plantation area is 156.8ha (373.3feddans) and the net forest area is currently 128.5ha (305.8feddans) which is less than the official 500feddans. Successful tree species are Eucalyptus citriodora and Casuarina equisetifolia because of its drought resistance. Eucalyptus camaldulensis shows good growth but has problems with pests and is browsed by animals. Cupressus are in a bad health status. Khaya showed good increment but bad quality because of lacking management and was possibly attacked by shoot borer. Other species are of experimental status. The biophysical environment with desert climate and sandy soils are big challenges for forest management. There is still no national policy or laws to regulate forest plantations in Egypt. The situation of the actual management of the plantation and the skills of the workers show that technical silviculture and management planning can be improved to foster silvicultural results. The stakeholder analysis revealed severe conflicts of interest with the local population. Browsing of livestock in the plantation determines silvicultural success and the high amounts of heavy metals in the plants are a potential health risk for livestock and humans which challenges the "safe" use of treated waste water.

Chapter 3 is dedicated to the silvicultural management planning and overall management recommendations. The plantation area is divided in productive, protective, demonstration and experimental areas. A rotation length of ±13 years was calculated until trees will reach a commercial target DBH of 20cm. A **HARVESTING PLAN 2013-2022** is developed to systematically cut and replant stands at the end of rotation. Silviculture focuses on Eucalyptus citriodora and Casuarina to improve wood production. Other species like Khaya shall be maintained as necessary. The implementation of a general silvicultural **WOOD PRODUCTION SCHEME IN 5 STEPS** will help to improve wood production and wood quality and to maintain a healthy forest plantation. The market orientation of silvicultural production must be improved. The irrigation system is in a critical condition (only two pumps are working out of seven) and must be repaired to guarantee the future success of the plantation. Socio-economic problems must be solved and

organizational structures and decision making procedures improved. Necessary activities are impeded by inappropriate organizational structures.

Chapter 4 gives an outlook of potential extension of the forest area financed with funds from the CO_2 market.

Chapter 5 concludes the work done.

As far as opportunities are concerned, the success of the plantation depends on the implementation of the plan's recommendations. A properly managed forest plantation can in fact be a source of valuable wood and biomass but also a carbon sink that can be exploited for the acquisition of carbon credits in the international market, as an alternative source of income.

Moreover, provided that the project will continue, an innovative system for wastewater treatment will be put in place in the Serapium forest, aimed at enhancing the capacity of the plantation to capture and store carbon and organic matter in the soil, whereby increasing the fertility of dry lands. The FAO project also proposes the establishment of a forest education center in the Serapium plantation, to be used to train technicians and experts in the field of forest inventory and data collection. Awareness raising is needed in the Undersecretariat for Afforestation, among plantation workers and local population on potential health risks associated with the uncontrolled use of treated wastewater. Consumption of plant material which is contaminated with heavy metals can be dangerous to humans or animal organisms.

URGENT ACTIONS	RESPONSIBILITY
✓Repair of the pumps and redesign of the irrigation system.	MALR, UAE
✓Analysis of health risks for humans and animals due to pathogens and high content of heavy metals in TWW and plant material (Hygienic measures and access restrictions to the plantation)	UAE, Universities
✓Prevent browsing and find compromise with animal owners to reduce plant damages.	MALR, UAE, Plantation management
✓Definition of a clear purpose, economic, social, ecologic goals and production targets for Serapium. Market analysis for wood products. Restructure of responsibilities within the institutions to facilitate silvicultural decision making at plantation level.	MALR, UAE, Universities
✓**Implementation of the Management Plan 2013-2022**	
–Improvement of silvicultural activities by following the **WOOD PRODUCTION SCHEME IN 5 STEPS.** –Implementation of the **HARVESTING PLAN 2013-2022** to guarantee regular annual harvests. –Chronological or thematic **documentation** of all activities on plantation level in a structured system (e.g. based on parcel numbers)	UAE, Plantation management, workers

Contents

Abbreviations and acronyms

AHA	Annual harvestable area
BA	Basal area
DBH/Dbh	Diameter at breast height (1.30m)
EEAA	Egyptian Environmental Affairs Agency
EPAP	Egyptian Pollution Abatement Project
FAO	Food and Agricultural Organization of the United Nations
FMP	Forest Management Plan
FRA	FAO - Global Forest Resources Assessment
GIS	Geographic Information System
GPS	Global Positioning System
GS	Growing stock
H_{tot}	Total tree height
HV	Harvestable volume
MAI	Mean annual volume increment
MALR	Ministry of Agriculture and Land Reclamation, Egypt
MSEA	Ministry of State for Environmental Affairs, Egypt
MHUUD	Ministry of Housing Utilities and Urban Development
NFMA	FAO - National Forest Monitoring and Assessment
NTS	Non tree species
SP	Sample plot
TS	Tree species
TWW	Treated waste water
UTM	Universal Transverse Mercator
WGS	World Geodetic System

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Overview Stakeholder assessment.
Overview Products and markets.

1.Framework of the Forest Management Plan 2013-2022

General purpose of the Forest Management Plan 2013-2022

The Forest Management Plan of Serapium forest is the result of the joint efforts of all project partners involved in the establishment and management of forest irrigated with treated waste water (TWW) in Egypt. The purpose of the Forest Management Plan for Serapium Forest is supposed to be the main document for the sustainable silvicultural, ecologic and social planning of Serapium forest plantation for the period 2013-2022.

Sustainable forest management is the process of managing forests to achieve clearly specified objectives with regard to the production of a continuous flow of desired forest products and services, without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment. This FMP intends to realize sustainable forest management to achieve the objectives defined by the UAE. Planning and recommended silvicultural treatments are based on the analysis of the current conditions at the plantation as they were found during the forest inventory carried out in September 2012.

Management objectives of the Serapium forest plantation

The Ministry of Agriculture and Land Reclamation (MALR) with the Undersecretariat for Afforestation and Environment (UAE) defined the general purpose of the forest plantations irrigated with TWW in the "National Programme for the Save Use of Treated Sewage Water for Afforestation". During the "Integrated Forest Inventory Training" held at Serapium forest plantation in September 2012 these main objectives were classified into ecologic, social and economic objectives with an indicator for the importance of each objective for Serapium forest. The overview of the objectives is shown in figure 1.

	Ecologic	Social	Economic
Very important	-Use of Waste Water -Desertification mitigation		
Important	-CO2 fixation	-Job creation and income -Research and capacity building	-Sale of wood products
Preferable	-Biodiversity -Soil improvement	-Rural development, -Education and recreation for citizens	-Sale of Non Wood Forest Products (NWFP) -CO_2 Certificates

Figure 1: Objectives for Serapium forest plantation

The classification reflects the opinion of the plantation management at Serapium and of the participants of the "Integrated Forest Inventory Training".

Ecologic objectives

Rivers and marine ecosystems in Egypt are under high risk to degrade by the negative influence of waste water. Therefore one of the main purposes of the plantations irrigated with TWW is to use a high quantity of the waste water to prevent further pollution. The mitigation of desertification and sand dune fixation are also an important ecological purpose of forest plantations on local level. The role of the plantation to store CO2 must be seen on country level. The plantations can contribute to the national goals of CO_2 emissions mitigation. Compared to the desert ecosystem, the ecosystem of a forest plantation is characterized by a high number of different habitats for many plant and animal species and may therefore contribute to a higher biodiversity in the region. The allocation of biomass and nutrients can contribute to an improvement of the soil for future forest plantations or other agricultural purposes, depending on the conditions for pedogenesis and the level of contamination by the TWW.

Social objectives

Serapium forest and other plantations offer job and income opportunities in rural areas. Capacity building in the field of forest management and forest work is an important objective for all associated institutions. That means also to increase research activity in the forest sector and practical field experiences of researchers. Rural development, in the sense of a higher attractiveness of the region and as origin for more economic and settlement activities of the private sector, can be regarded as a very important objective on national level. The newly established ecosystems shall also be an opportunity for Egyptian school classes and interested citizens to learn more about nature and experience the recreational effects of a forest plantation.

Economic objectives

The economic objectives are mainly linked to wood production. In a macroeconomic perspective, an increased national wood production through plantations can supply local wood markets and therefore decrease the need for wood imports. On operational level the sale of wood products like logs, fuel wood or stakes and poles or the sale of other NWFP is supposed to be the main source of revenues to cover the expenses at plantation level.

Implications for management activities and silvculture

The classification shows that the ecological objective of using waste water is of higher importance than other objectives. The use of a high quantity of waste water is directly linked to wood production. The higher the biomass production through woody species, the higher is the amount of water consumption. The commercialization of the produced wood is an objective on second level and is necessary to amortize expenses at plantation level. The improvement of wood quality is linked to the economical objective and aims to increase the revenues from the commercialization of the wood if the market allows higher prices for wood of better quality. Another positive effect of improving wood quality is the adoption of better silvicultural treatments at the plantation and therefore it can be regarded as driving motivation for capacity building. The mentioned social and ecological objectives must be included into management activities as good practice for social and ecological sustainability. The following management objectives are deduced from the above described overall objectives and shall guide the strategic work of this FMP to guarantee sustainable forest management:

Objective 1: To guarantee ecological, social and economical sustainability of the plantation.
Objective 2: To increase wood production for local markets.
Objective 3: To improve the wood quality at the plantation.

2.Status quo of the Serapium forest plantation

History

The Serapium Plantation Forest was established in the year 1998 by the Ministry of State for Environmental Affairs, in cooperation with the Ministry of Agriculture and Land Reclamation of Egypt to implement the "National Programme for the Safe Use of Treated Sewage Water for Afforestation". Initially the main objectives of the plantation were to use treated waste water (TWW), preventing its discharge in the environment, and to combat desertification. In recent years, in addition to the above mentioned purposes, the focus has shifted also toward the possibility of producing valuable wood and generating an income stream.

The total area of the plantation increased from 126 ha (300 feddan) in the year 2005 to 252 ha (600 feddan) in 2010 (FAO 2010a: 15). In October 2012, during the specific inventory carried out for this management plan, total area was estimated to be 241 ha (574 feddans), including the area of the TWW facilities.

Location

The Arab Republic of Egypt is comprised between 22°N - 32°N and 25°E - 35°E (FAO 2010a: 5, FAO 2011a: 5) and covers a total surface of 1,001,450 km^2. The Serapium forest is located in northeastern Egypt, within the Governorate of Ismailia, roughly 16 km south of the town of Ismailia and next to the Suez Channel and the Serapium village. The plantation is positioned to the western side of the road connecting Hurghada to Ismailia.

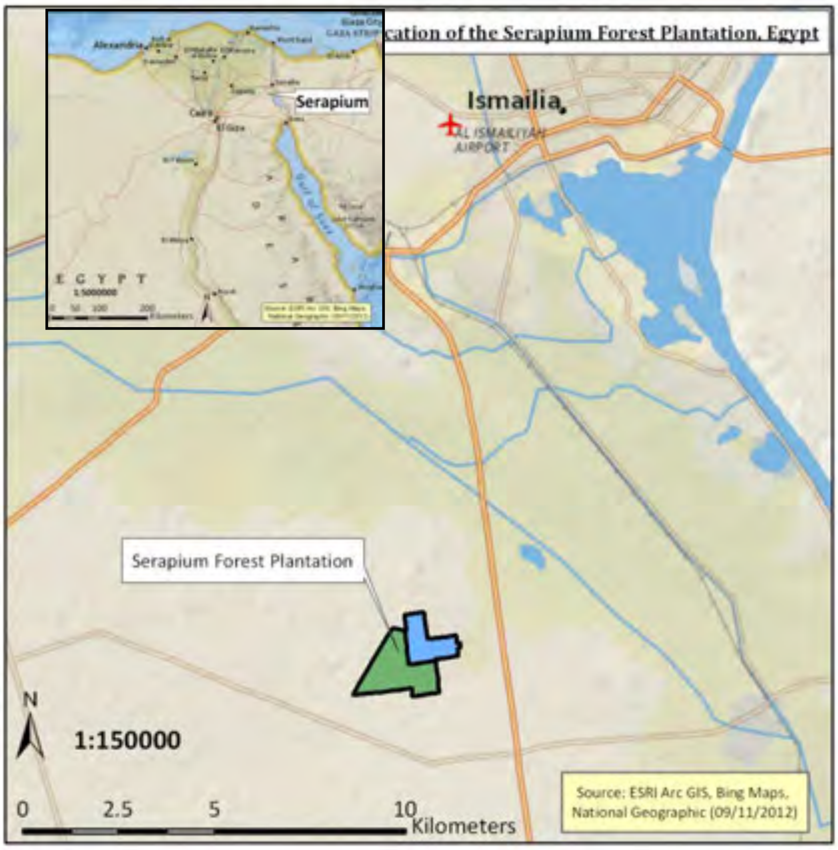


Figure 2: Location of the Serapium forest plantation (Graphic A. Kress, FAO).

Biophysical environment

Climate

According to the FAO categorization, the site of the plantation falls into the tropical desert (FAO 2001: 103) eco-region and it is located in the physiographic unit of the Egyptian eastern desert, in the Governorate of Ismailia. The site is about 30 m above sea level with an annual rainfall of 29 mm/year, medium temperatures of 21.6 °C, relative humidity of 53.9%, a medium wind speed of 2.5 m/s. The medium annual evapotranspiration (ETo) is 1817 mm/year (see table 1).

Table 1: Climatic characteristics at Serapium forest plantation (FAO AQUASTAT 2012)

Month	Prc.	Prc.	Prc. cv	Wet days	Tmp. mean	Tmp. max.	Tmp. min.	Grnd Frost	Rel. hum.	Sun shine	Wind (2m)	ETo	ETo
	mm/m	mm/d	%	days	°C	°C	°C	days	%	%	m/s	mm/m	mm/d
Jan	5	0.2	133.1	4.5	13.7	19.1	8.4	2.2	58.9	68.1	2.2	75	2.4
Feb	5	0.2	127.8	3.5	14.9	20.7	9.2	1.7	56.1	70.1	2.6	89	3.2
Mar	5	0.2	124.7	2.5	17.0	23.0	11.0	0.7	52.1	71.7	2.8	131	4.2
Apr	2	0.1	175.1	1.1	21.3	28.1	14.6	0.1	46.0	74.1	2.8	172	5.7
May	2	0.1	313.7	0.6	24.3	31.5	17.1	0.0	45.1	78.8	2.8	211	6.8
Jun	0	0.0	436.6	0.0	27.2	34.4	20.1	0.0	48.4	87.3	2.8	226	7.5
Jul	0	0.0	446.3	0.0	28.5	35.2	21.8	0.0	51.9	85.3	2.5	225	7.3
Aug	0	0.0	446.6	0.0	28.4	34.9	22.0	0.0	54.6	86.5	2.4	210	6.8
Sep	0	0.0	448.8	0.0	26.6	32.8	20.4	0.0	56.4	81.9	2.4	172	5.7
Oct	1	0.0	226.9	1.0	23.6	29.7	17.5	0.0	57.2	82.9	2.4	141	4.6
Nov	5	0.2	174.2	2.0	19.3	25.1	13.5	0.1	59.5	76.7	2.0	93	3.1
Dec	4	0.1	135.5	3.4	15.1	20.6	9.7	1.1	61.0	65.5	2.0	72	2.3
Total	29											1 817	
Mean					21.6				53.9	77.4	2.5		

(*Prc.* = Precipitation; *Prc. cv* = Coefficient of variation of precipitation; *Wet days* = Number of days per month with >0.1mm of precipitation; *Tmp. mean*= Mean temperature; *Tmp. min/max* = minimum/maximum temperature; *Grnd Frost* = Number of days per month with ground frost; *Rel. hum.* = relative humidity; *Sun shine* = Sun shine as percentage of day length; *Wind(2m)* = wind speed at 2m; *ETo* = Reference evapotranspiration)

Topography and soils

The site of the plantation is characterized by flat land, with an estimated altitudinal difference of 10 m maximum. This can produce different water regimes in the soil and therefore lead to inhomogeneous plant growths. As described in the Interim report of the UAE (UAE 2012: 2), the soil belongs to the textural sand class, and displays the following particle size distribution.

Sand	92.50%
Silt	3.28%
Clay	4.22%

The soil also presents the following chemical values:

E.C. soil conductivity	1.37
SP	19.4
PH	7.07

Natural vegetation cover and biodiversity

The impact of desert forest plantations on biodiversity was investigated by FARAHAT & LINDERHOLM (2012). The diversity of the understorey vegetation of four planted forests in Egypt with adjacent desert areas was compared and the authors conclude that planted forests contribute positively to the overall diversity. The authors trace the increment in biodiversity back to the availability of water and nutrients, provided by the irrigation system. A negative effect is the decrease in diversity of native desert species from 66% in desert areas to 44% inside the forests. This change in plant composition is mainly caused by a higher presence of agricultural weeds and plants. Desert shrubs and trees are even more excluded from the plantation areas due to the scarcity of light under the canopy cover. Tamarix aphylla is one of the native shrubs. The authors propose wider spacing for tree planting to foster growth of native shrubs in the plantations, but wider spacing would contradict silvicultural objectives, what is not considered. The understorey plants and shrubs are important as habitat and as food source for wildlife and livestock. This conclusion is confirmed by observations during the "Integrated Forest Inventory Training" in September. Many signs for wild animals (fox holes, birds, chameleons, insects, etc.) were found. What the authors do not take into consideration is the contamination with heavy metals and the potential negative impacts on wildlife and livestock.

Policy statement and legal status

Egypt does not have a formal national forest policy or an adequate legislation to direct and manage tree planting, protection and harvesting. In September 2007, the Government of Egypt requested the support of the Food and Agriculture Organization of United Nations (FAO) for the formulation of a Forest Policy and Strategy plan for the development of the sector. This exercise was carried out following a participatory approach in consultation with all concerned stakeholders through the FAO project TCP/EGY/3103 '*Assistance to forest policy formulation, legislation and institutional reorganization*' (MALR, UAE 2009: 4). The *Forest Policy and Strategy* stressed the need to develop a general strategy for the development of the forestry sector. It also emphasized the lack of technical capacity in the fields of national management plan, national forest inventories and of qualified personnel to fulfill the sector's goals. A new forest law has been recently introduced but has not been approved until now by the parliament.

Government allocated funds to the forestry sector in Egypt are very limited. For the years 1998 to 2008 this amounted to less than 2.5% of the Ministry of Agriculture and Land Reclamation budget (MALR, UAE 2009: 17).

In Egypt, where the volume of municipal wastewater is estimated at 2.4 billion cubic meters per year (MSEA 2004: 2) there are 22 operating wastewater treatment plants and another ca. 150 under construction (FAO 2002: 3). The Minister of Agriculture and Land Reclamation, with the Decree No. 603/ 2002, prohibits the use of wastewater, either treated or untreated, for irrigation of traditional field crops. The use of waste water irrigation is limited to the cultivation of timbers and ornamental trees, providing that all the measures to protect the health of workers that handle this type of water are strictly abided (WAHAAB & OMAR without year: 15). Only non-edible trees and tree products, as in the case of wood production, can be irrigated with blackwater (FAO 2002: 3): this is the main concern of the National Program for the Safe Use of Treated Sewage Water for Afforestation. To underline the importance of the use of TWW for afforestation, the national law 4/1994 (amended by Law No. 9/2009 on the Discharge of Liquid Wasted to Marine Waters) prohibits the discharge of wastewater into the sea, either directly or indirectly. In addition, law No. 4 banns the discharge of wastewater containing non-degradable polluting substances (MSEA, EEAA, EPAP 2003: 60).

Institutional and administrative framework

The Undersecretariat for Afforestation and Environment (UAE) is part of the Ministry of Agriculture and Land Reclamation (MALR) and is the main public institution in charge of forest resources management in Egypt. The UAE is responsible for the management of the Serapium Forest Plantation. The annual budget for maintenance and operation of the plantation is provided by the MALR. The Serapium Plantation is directly managed by a manager from the UAE, who is nevertheless bound to defer any decision about the management of the plantation to the UAE.

The main objectives of the Egyptian forest administration, as mentioned in the *Forest Policy Statement and Strategy*, are to develop financial and administrative mechanisms in support of the sector activities, to provide a framework for the sustainable and rational management of the resource and to strengthen and restructure the UAE with the establishment of an autonomous and efficient forest administration (MALR, UAE 2009: 9).

The Ministry of Housing Utilities and Urban Communities (MHUUC) is responsible for the planning and construction of municipal wastewater treatment plants (WAHAAB & OMAR without year: 14) and for the provision of the TWW.

Staff and labour

39 workers were employed at the plantation in September 2012. The workers are hired according to their professional experience for specialized tasks as noted in table 2. Usually they live in the village of Fayed close to the plantation or in the surrounding settlements. Only few workers, mostly guards, live within the plantation area in small houses or huts.

Table 2: Number of workers according to specialization in 2012

Specialization	Number of workers
Forest worker	10
Irrigation worker	7
Nursery worker	1
Electrician	1
Mechanic	1
Driver	3
Safety guard	16
Total	**39**

The forest workers do all the silvicultural work like planting, cutting and pruning. Irrigation technicians regularly control and repair the tube system if needed. The nursery technician is responsible for optimal breeding conditions in the nursery and the production of high quality seedlings according to the demand at the plantation. Safety guards shall prevent unauthorized access to the premises and theft of equipment. Every worker is responsible for his field of duty and nearly no interdisciplinary division of labor takes place.

It was noticed during the field visit in September 2012 that safety standards are not adhered to. The workers wear inappropriate footgear for forest work and no safety equipment or protective clothing is used for the work with the chainsaw. Rudimentary chainsaw handling skills exist, however it was observed that felling procedures are a risk for all involved workers because safety zones are not respected. Knowledge and skills in silvicultural techniques like pruning or other tending operations need to be improved.

Infrastructures, accessibility and equipment

Buildings at the plantation are in good condition. A new building for soil analysis and other research activities will soon be opened. The infrastructure for electricity and fresh water supply at the plantation is working well.

The accessibility of the plantation area is excellent. The main roads are in good condition and each parcel of the forest area can be easily reached by car. Some secondary sand roads between the parcels cannot be accessed by car due to deep sand but which is not necessary everywhere. To enter the planted parcels with vehicles is hindered or impossible without the destruction of the above ground irrigation lines. This restriction would make it necessary to manually extract wood from removals or thinning operations.

Several vehicles are available for use at the plantation. Besides Pick-up cars, which serve for the transport of workers and small equipment, tractors are in use for heavier work or the transport of heavier equipment or water tanks.

The availability of specialized forest equipment is very limited. There are one to two chainsaws in use at the plantation but they are too big for the current tree diameters and the handling is therefore more dangerous and not ergonomic. The maintenance of the tools is poor. The existing axes and handsaws need sharpening to improve ergonomics at work and to prevent damage on the trees due to edgeless tools. Protective clothing, safety equipment or first aid kits are inexistent. Heavier forest equipment like winches or loaders is inexistent and investment in this kind of equipment is only recommendable if wood production and the future dimensions of the logs increase.

Water and irrigation system management

Waste water treatment

The provision of TWW is regulated by the Ministry of Housing, Utilities and Urban Development (MHUUD) on the basis of the *National Program for the Safe Use of Treated Waste Water for Afforestation* and it is provided at no cost for afforestation practices to the UAE. According to the manager of the Serapium plantation, the TWW basins of Ismailia can provide 90,000-130,000 m^3/day of TWW. The water is pumped from the accumulation basins into the plantation. The UAE is responsible for the maintenance and operation of these pumps.

Before being provided to the plantation, the water is treated at a preliminary level to remove the solid and other large materials then it moves into some stabilization ponds (basins) located next to the plantation for a secondary treatment. The two levels of treatment are summarized below:

<u>Primary Treatment</u>: the objective of the primary treatment is the removal of organic and inorganic solids by sedimentation and the removal of the remaining floating foamy materials by skimming. Approximately the primary treatment removes: 25 - 50% of the incoming biochemical oxygen demand (BOD), 50 - 70% of the total suspended solids (SS), and 65% of the oil and grease. Some organic nitrogen, organic phosphorus, and heavy metals associated with solids are also removed during primary sedimentation but colloidal and dissolved constituents are not affected (FAO 1992: 23).

<u>Secondary Treatment</u>: the objective of secondary treatment is the further treatment of the effluent from primary treatment to remove the residual organic and suspended solids. The treatment involves the removal of biodegradable dissolved and colloidal organic matter, using aerobic biological treatment processes. In the basins, water is moved and oxygenated with some rotors (FAO 1992: 24) which entails significant energy consumption. After these treatments, the remaining sludge is collected in specific basins and is not used in the plantation.

Neither the plantation manager nor the UAE guaranteed the purity of the water after the treatment. It must therefore be assumed (until proofed) that the water still contains pathogens.

The water also contains high amounts of heavy metals (Ghorab et al. 2011). The possible impurity and contamination of the water with heavy metals induces certain health risks for animals and humans. Highest standards for handling the water should be implemented.

Irrigation system

The pumping facilities are located in the north-eastern section of the Serapium plantation. These are made up of two pumping systems with seven electric engines (also named pumps):

- The first system consists of three main engines: two 100 hp and one 150 hp;
- The second pumping system has four main engines: two 100 hp engines, one with a 180 hp and another with 270 hp.

Since the engines cannot operate without water already in the system, two additional small engines are needed to start pumping from the basins. Then the wastewater runs through 12 filters and enters the irrigation network. A manually activated dripping irrigation system is used in the plantation. The irrigation network is composed of three level pipes of decreasing diameter. The final segment of the network is made up of 18 mm diameter pipes, which are connected every 3 m to the second line of irrigation pipes, and have discharging holes every 3 m. these provide water directly to the trees. Figure 3 gives an overview of the irrigation system.

Only two pumps, out of the seven in place, are currently working. Five pumps broke in the first months of 2012 and have not yet been repaired so far. The breakdown of the pumps is mainly caused by the fact that the irrigation system is not customized for the use with TWW. The impurities in the TWW accelerate the normal wearing of the system. The plantation manager reported that at the moment every planted parcel is provided with only 4 hours/month of irrigation, compared to the 16 hours/month that could be provided if the system was fully functional. Apart from the duration of irrigation per parcel the quantity of water delivered to the trees is unknown. It is therefore unclear if the irrigation system matches water requirements of the trees or if too much water is delivered to the parcels. An irrigation schedule based on the capacity of the pumping and tube system and adapted to plant requirements does not exist.

A rough estimation was calculated with the help of irrigation engineers based on the available data and the following assumptions.

- Only two pumps are in operation (each with estimated 100Kw power).
- Each parcel is irrigated for approximately 4 hours/month.
- Each plant receives water from a single discharging nozzle.
- Plant density is approximately 1100 p/ha, therefore there should be 1100 nozzles per ha.
- Constant pressure of the water that runs through the discharging nozzles.

The total amount of water provided by the current irrigation system is estimated to be 1000 mm / m^2 / year. Signs of drought stress at the plants show that the current water supply of 1000mm, also considering the high evaporation rate of 1815mm per year, is not sufficient.

Another problem occurs due to the pipe system. Pressure in the 18mm 3^{rd} level pipes seems to be decreasing with increasing distance from the 2^{nd} level pipe. Thus, towards the parcel margins water supply is less than in the parcel center. With the better water supply in the parcel center the trees show better growth than at the parcel margins. The growth gradient can be observed in every parcel at the plantation. An overview of the irrigation system and the implication on the growth of the plants gives figure 3.

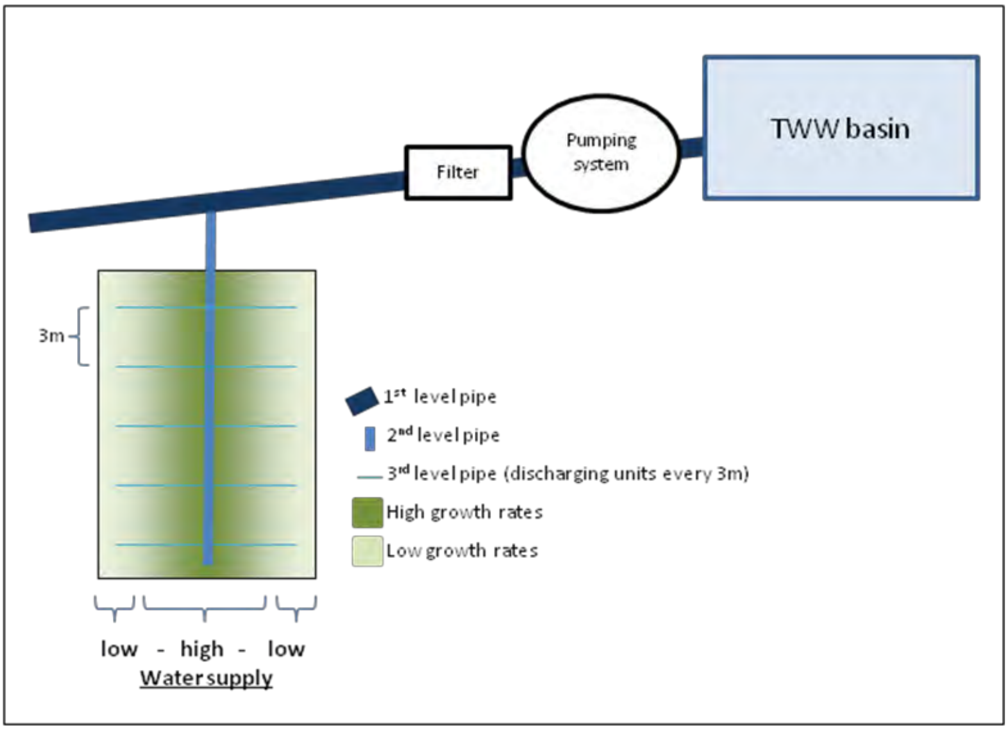


Figure 3: Irrigation system at Serapium forest plantation

Current silvicultural practices

Nursery

Tree species which are currently reproduced at the plantation are Ecualyptus and Pinus of which only Eucalyptus is used for planting. The seeds are placed in polybags filled with a heavy and dense mixture of clay and sand. After 2-3 months the seedlings are supposed to be planted on the parcels. The seedlings are irrigated by a sprinkler system using TWW. The health risk due to direct contact of the nursery workers with possible contaminants in the water cannot be denied. Drainage or ventilation of the seedlings is inexistent. Seed beds of Eucalyptus citriodora are contaminated with seeds from Eucalyptus camaldulensis trees which grow next to the nursery. Effect is that seedlings from these two species are raised mixed and no further differentiation is done before planting. Parcels that shall be planted with only Eucalyptus citriodora are receiving thus a certain amount of Eucalyptus camaldulensis trees. Results will be mixed stands of these species. The seedlings of E. camaldulensis are affected with galls and leaf minors. A high mortality rate and loss of the Eucalyptus camaldulensis seedlings can be expected. In general no quality control of seedlings is conducted before planting.

Pruning

Pruning skills of the workers are rudimentary, techniques and results are very poor. Recent pruning caused more damage to the trees instead of improving the quality. Pruning operations were carried out when trees already reached diameters (>12-15cm) at which no reasonable growth of branchfree stem wood can be expected. Branches are cut off too far from the stem, branches have been partly broken or thick branches were cut off which left big injuries to healthy trees. Occlusion of the wounds is nearly impossible. Trees were selected regardless of quality and health status, which shows that pruning activities lack considerations of production targets and market analysis. The UAE and the plantation management have not defined production targets for pruned trees (minimum expected diameters of branchfree stem wood), or whether these targets can be achieved or whether the pruned wood will reach higher market prices.

Thinning

Silvicultural parameters or hazards control are not considered for the planning of thinning operations. An indicator for launching thinning operations is the crown density, which indicates the competition of trees for light and growing space needed for good growth. In the older Khaya stands no thinning was carried out, although the crowns are densely interlocking and the trees are competing for growing space. On the other hand Casuarina stands (2006) were thinned although there was no competition for light (also because Casuarina has very light crowns) or growing space. Thinning operations are carried out by the plantation workers.

Harvesting

Harvesting operations are carried out by external companies or entrepreneurs who would buy the standing trees of the respective parcels. They cut and remove the trees with own workers. The plantation workers observe and control the procedures.

Plantation area and tree species distribution

A forest map "Serapium Forest Ismailia – Tree Species Distribution 2012" (see annex) was produced with ESRI *ArcGIS Desktop 10* and the service for aerial photos 'Bing Maps Aerial'. Different areas of the plantation were distinguished as shown in figure 4.

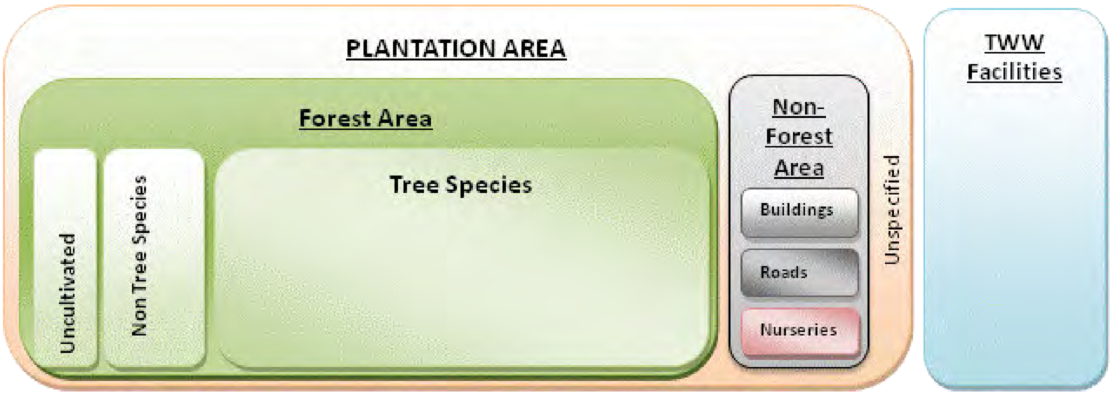


Figure 4: Scheme of the gross and net areas of the Serapium forest plantation, Ismailia

First information about the tree species distribution was provided by the UAE and the plantation management and during the "Integrated Forest Inventory Training", held in September 2012, the spatial distribution of the species was verified to produce a correct forest map. The sizes of the areas are shown in the following table 3.

Table 3: General spatial information of the Serapium forest plantation, Ismailia, in 2012 (1ha = 2.38 feddan)

Area	ha	Feddan	% of Plantation Area	% of Forest Area
Tree Species	96.3	229.3	61.4%	75.0%
Non-Tree Species	13.0	30.8	8.3%	10.1%
Uncultivated Parcels	19.2	45.7	12.2%	14.9%
Forest Area	**128.5**	**305.8**	**81.9%**	**100.0%**
Buildings	0.1	0.3	0.1%	
Roads	12.0	28.6	7.7%	
Nurseries	0.2	0.5	0.1%	
Unspecified	16.0	38.1	10.2%	
Non-Forest Area	**28.4**	**67.5**	**18.1%**	
Plantation Area	**156.8**	**373.3**	**100.0%**	
TWW Facilities	84.3	200.6		
Total	**241.1**	**573.9**		

The identified current "Plantation Area" of 156.8 ha (373.3 feddans) (not taking into account the "TWW Facilities" area) is smaller than the original figure of 500 feddans (210.0 ha) (or sometimes even 1000 feddans) that is mentioned in official documents. The main area of interest for forest management is the net forest area. Table 4 gives the area per species.

Table 4: Area per species and year of planting at Serapium forest plantation in September 2012

Species and year of planting	Species Area, ha	Species Area, feddan	% of Forest Area	% of Non-Tree Species	% of Tree Species
Sisal (Agave sisalana) 2002	10.2	24.3	7.9%	78.7%	
Bambus 2007	1.1	2.7	0.9%	8.8%	
Jatropha curcas	1.5	3.5	1.2%	11.5%	
2006		0.0			
2010		0.0			
Jojoba (Simmondsia chinensis) 2010	0.1	0.3	0.1%	1.0%	
TOTAL Non-Tree Species	**13.0**	**30.8**	**10.1%**	**100.0%**	
Casuarina equisetifolia	**3.9**	**9.3**	3.1%		4.1%
2002	1.7	4.1			
2006	1.6	3.8			
2011	0.6	1.4			
Cupressus sempervirens 2002	**20.7**	**49.2**	16.1%		21.5%
Dalbergia sissoo 2007	**2.5**	**6.0**	2.0%		2.6%
Eucalyptus camaldulensis	**16.3**	**38.9**	12.7%		16.9%
2004	0.6	1.4			
2006	1.5	3.5			
2008	2.8	6.7			
2009	0.3	0.6			
2010	2.7	6.4			
2011	2.1	5.0			
2012	6.4	15.2			
Eucalyptus citriodora	**18.3**	**43.5**	14.2%		19.0%
2007	1.6	3.8			
2008	5.0	12.0			
2010	9.5	22.7			
2012	2.1	5.1			
Harpullia 2007	**0.8**	**2.0**	0.7%		0.9%
Khaya grandifoliola 2010	**0.6**	**1.3**	0.4%		0.6%
Khaya senegalensis	**25.0**	**59.5**	19.5%		26.0%
2002	5.6	13.2			
2004	6.1	14.6			
2007	13.3	31.7			
Pinus halepensis	**4.7**	**11.1**	3.6%		4.8%
2002	2.5	5.9			
2008	0.9	2.2			
2009	1.3	3.0			
Terminalia arjuna	**3.5**	**8.3**	2.7%		3.6%
2005	1.9	4.4			
2007	1.6	3.9			
TOTAL Tree Species	**96.3**	**229.3**	**75.0%**		**100.0%**
Uncultivated Parcels	19.2	45.7	14.9%		
Forest Area	**128.5**	**305.8**	**100.0%**		

The net area for each species in total and for each planting year is given in hectare (“Species Area, ha”) and in feddans (“Species Area, feddan”). The total area of each species is also given as a percentage of the forest area (“% of Forest Area”) or respectively as percentage of the area of tree species (“% of Tree Species”) or the area of non-tree species (“% of Non-Tree Species”).

It shows that Sisal (Agave sisalana) has the highest share among the non-tree species, whereas Bambus, Jatropha curcas and Jojoba (Simmondsia chinensis) are represented only on a small area and can be regarded as experimental.

Among the tree species Khaya senegalensis is the most represented. Cupressus sempervirens), Eucalyptus citriodora and Eucalyptus camaldulensis show the next higher shares in the plantation. The area of Pinus halepensis was reduced in the last years, whereas the area of Casuarina equisetifolia increased. The other tree species Terminalia arjuna, Dalbergia sissoo, Harpullia and Khaya grandifoliola play a marginal role at the plantation.

Forest inventory

Forest inventory design

Before the start of the field mission the planning and preparation of the sampling inventory was made difficult by the following framework conditions:

- There were only imprecise data available for the total area and the area of each tree species.
- The age of the tree species was unknown. Stratification for the sampling by species and age was therefore not possible.
- On aerial photos it could be observed that the growth performance of each plot was very heterogeneous depending on the location of the tree. The plants show best growth in the middle of each parcel, presumably along the main irrigation tube. The growth is distinctly lower towards the edges of a parcel and with increasing distance from the main irrigation tube.
- There were no previous inventory data available nor has there been time to carry out a pre-inventory of plots for each tree species (or stratum of species and age) to run a statistical analysis of the required sample size and for setting precision targets.

In view of this situation the sample design was determined as follows:

- Stratification by tree species and age (planting year).
- Sample area covering minimum 1.5% of the area of each stratum (Empirical approach due to missing previous inventory data to define precision targets).
- Rectangular sample plots with a size of 21m x 21m[1]. Rectangular sample plots fit the regular planting patterns of the plantation and facilitate orientation within the stand. In contrary to circular sample plots border trees can be avoided[2]
- Random distribution of sample plots within each stratum to minimize a bias regarding the observed growth gradient in each parcel.

The required number of plots was randomly selected with the GIS system and Microsoft EXCEL. Column “Required plots” of table 5 gives the number of required sample plots per stratum to cover minimum 1.5% of the stratum area. As a result the total number of plots was calculated at 35, however some of these stands did not reach measurable dimensions and were excluded from measurement. Other plots were added during the inventory so that eventually a total number of 42 plots were measured (column “Measured plots”). The column “Area covered with measured plots” shows the real percentage of coverage.

[1] The initial planning and selection of the sample plots was conducted with sample plots of 20m x 20m. However this design was changed during the course of the inventory as the planting distance in the plantation is always 3m x 3m. Rectangular sample plots of 21m x 21m fit better the situation of the plantation, including always 7x7 tree rows.

[2] This experience was made by FAO colleagues during a field visit at Serapium Forest in July 2012 and is recommended in forest inventory literature (e.g. Zöhrer 1980:21).

Table 5: Required sample plots per stratum (tree species and planting year)

Species and year of planting	Species Area, ha	Species Area, feddan	Sample Area, m^2	Required plots (21mx21m = 441m^2)	Measured Plots	Area covered with Measured Plots %
Sisal (Agave sisalana) 2002	10.2	24.3	1529.5			
Bambus 2007	1.1	2.7	171.6			
Jatropha curcas	1.5	3.5				
2006		0.0	206.5			
2010		0.0	16.9			
Jojoba (Simmondsia chinensis) 2010	0.1	0.3	19.5			
TOTAL Non-Tree Species	**13.0**	**30.8**				
Casuarina equisetifolia	**3.9**	**9.3**				
2002	1.7	4.1	260.6	1	1	2.5%
2006	1.6	3.8	241.8	1	1	2.7%
2011	0.6	1.4	85.5	1		
Cupressus sempervirens 2002	**20.7**	**49.2**	3100.9	8	8	1.7%
Dalbergia sissoo 2007	**2.5**	**6.0**	380.1	1	2	3.5%
Eucalyptus camaldulensis	**16.3**	**38.9**				
2004	0.6	1.4	91.0	1	1	7.3%
2006	1.5	3.5	219.2	1	1	3.0%
2008	2.8	6.7	425.2	1	2	3.1%
2009	0.3	0.6	40.4	1		
2010	2.7	6.4	400.2	1		
2011	2.1	5.0	317.6	1	1	2.1%
2012	6.4	15.2	955.3	3		
Eucalyptus citriodora	**18.3**	**43.5**				
2007	1.6	3.8	237.3	1	1	2.8%
2008	5.0	12.0	754.0	2	2	1.8%
2010	9.5	22.7	1432.2	4	5	2.3%
2012	2.1	5.1	320.6	1		
Harpullia 2007	**0.8**	**2.0**	126.6	1		
Khaya grandifoliola 2010	**0.6**	**1.3**				
Khaya senegalensis	**25.0**	**59.5**				
2002	5.6	13.2	833.5	2	4	3.2%
2004	6.1	14.6	922.3	3	3	2.2%
2007	13.3	31.7	1997.0	5	6	2.0%
Pinus halepensis	**4.7**	**11.1**				
2002	2.5	5.9	371.1	1	2	3.6%
2008	0.9	2.2	139.4	1		
2009	1.3	3.0	188.2	1		
Terminalia arjuna	**3.5**	**8.3**				
2005	1.9	4.4	280.1	1	2	4.7%
2007	1.6	3.9	245.8	1		
TOTAL Tree Species	**96.3**	**229.3**	**14448.8**	**35**	**42**	**1.92%**
Uncultivated Parcels	19.2	45.7				
Forest Area	**128.5**	**305.8**				

Table 6 shows the measured sample plots with individual plot number for identification in the GIS system. The coordinates[3] of the north east corner of each plot facilitate future access of the inventory area.

Table 6: Measured sample plots per stratum with GPS coordinates

Tree Species	Planting year	Plot Number (OBJECTID *)	Plot Number Old (OBJECTID)	East coordinate: North-east-corner (UTM36N, WGS1984)	North coordinate: North-east-corner (UTM36N, WGS1984)
Casuarina equisetifolia	2002	4930		425742	3372777
	2006	979	980, 20m west	426302	3372397
Cupressus sempervirens	2002	2315		426622	3372617
		4435		426162	3373317
		4468		426362	3373417
		2681		427122	3372677
		1695		427162	3372497
		3227		426942	3372857
		4368	4356, 20m south	426442	3373297
		1285		426742	3372477
Dalbergia sissoo	2007	2793		426542	3372697
		3071		426502	3372797
Eucalyptus camaldulensis	2004	3296	1562 new selection	425750	3372830
	2006	1180		426582	3372377
	2008	3049	2084 new selection	426970	3372750
		5168	4971 new selection	426730	3372250
	2011	47		426662	3372277
Eucalyptus citriodora	2007	1089	1111b	426462	3372437
	2008	231		427002	3372257
		324		427102	3372237
	2010	4700	39 new selection	426190	3373590
		4666	72 new selection	426370	3373570
		745		425982	3372357
		755		425982	3372317
		3348		425822	3372857
Khaya senegalensis	2002	3715		426402	3372997
		3722		426442	3372977
		3732		426442	3372937
		3805		426522	3372917
	2004	3435	1489 new selection	425990	3372850
		3546		426122	3372837
		3576		426202	3372917
	2007	1377		426122	3372497
		2018		426242	3372597
		2496		426122	3372657
		4103		426022	3373217
		4129		426002	3373097
		4200		425942	3373057
Pinus halepensis	2002	2362	2363, 20m west	426702	3372657
		1893	1894, 20m west	426802	3372557
Terminalia arjuna	2005	1393		426862	3372517
		1485		426962	3372437

Two field forms (F3-a1, F3-a2) have been used to assess tree and stand parameters. The first is important for the main stand parameters. The second was important for capacity building and forest training and includes more aspects for a professional stand description. The criteria of the parameters in field form F3-a1 were defined before and if necessary specified during the field inventory training held in September 2012. The definition of the criteria was guided by FAO standards and as defined by forest experts from TUM for the assessment of forest plantations in Egypt. The following explanations are taken from the field manual created for the field inventory training (FAO 2012):

[3] Settings for GPS receivers: World Geodetic System 1984, UTM zone 36N.

1. **Position N°:** Trees are planted in regular distances. Report here the consecutive number of the position of tree growth. Usually one tree grows in one position. It can occur that two or more trees grow in the same position and are therefore very close together (see the filled example of F3-a1 in the Annex).
2. **Tree N°:** Report here the consecutive tree number. If a tree is forked at a height of <1.30m, consider every stem of the fork as a single tree with its own individual number, but with the same position number.
3. **DBH (Diameter at Breast Height):** The diameter of a tree is measured according to international standard at the height of 1.30m which corresponds to an average human breast height.
4. **Commercial (Bole) Height:** For every tree species, in every country and even for every forest there are commercial heights that are based on the local end-use of the harvested wood. Commercial height depends on a set of defined standards. More generally commercial height should be measured from the foot of the tree to:
    a. **the first big branch, when the quality or form of the stem decreases reasonably**.
    b. **the lower base of a forked stem**.
    c. **the height of the stem where the diameter is around to 5 cm**.
    d. **For trees forked at a height <1.30m, consider the fork as the base of the stem and measure each stem from fork to one of the conditions (a, b, c) described above and also reported in Table 4 (Annex: Measurements)**

5. **Vitality**: The crown condition of a tree is an indicator of vitality. The main parameters to be considered here are the density of foliages or the appearance of dead branches (top dieback). For every tree species the density of foliages can change during the year and dead branches may be typical for some tree species (for example in the lower part of conifers). Therefore the vitality has to be set to a standard at the plantation for each tree species. That means that the condition of a single tree has to be compared with the condition of the surrounding trees of the stand of the same species or with the condition of trees growing under the same condition in other places. As general approach we will use categories as follows:
    a. **Healthy** (densely foliated, no top dieback);
    b. **Moderate Health** (fairly foliated, beginning top dieback);
    c. **Unhealthy** (poorly foliated, severe top dieback);
    d. **Dead.**
6. **Tree Quality:** The ability to classify the tree quality is very important, but at the same time it is difficult and needs training and experience. The tree quality also depends from the defined purpose of the stand or from the designated use of the wood. For example if the purpose is to have valuable wood for boards or veneers, a good quality tree has to be straight, the stem must be without branches, and the crown should be vital for good increment. Whereas a good quality tree for a shelterbelt can be of low height, with many branches and the stem form is irrelevant. **Note: To categorize tree quality it is important to look at the whole tree and evaluate whether it is worth to maintain it for the next coming years of silvicultural treatment.** Assuming that the purpose of the Serapium Forest is to produce better quality wood, the following quality of the tree need to be considered:
    a. **High** (straight trunk, free of fork, well formed crown, no defects);
    b. **Satisfactory** (slightly crooked, slightly forked, fairly formed crown, little defects);
    c. **Low** (sharply crooked, strongly forked, badly formed crown, severe defects)
    d. **Shrubby**

Tree quality will correlate with other parameters. For example a tree with a straight stem and without damages indicates a high quality stem, but the tree has to be classified as low quality tree if the crown is badly formed and/or damaged (low fork, broken branches, etc.). Such a tree is not worth to be left for the next years.

7.**Social class:** The following Figure shows the different social classes within a forest stand.

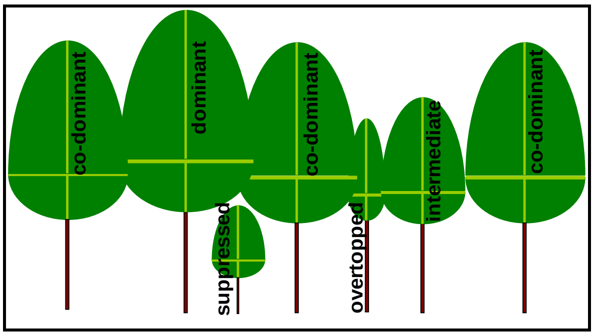


Figure 5: Social classes for tree stands (TUM, Forestry Department)

8.**Stem form:** According to the designated use of the trees, the grade of crookedness must be defined for every tree species at the plantation. Slightly crooked stems show small curves and deviations from a straight stem. Heavily crooked stems are multiply and heavily curved.

9.**Damage degree:** A definition of the severity of damages has to be found within the team for each tree species:

a.**Undamaged/healthy**;
b.**Slightly affected**;
c.**Severely affected**;

10.**Damage type:** The prevailing damage type.

a.**Abiotic** (climatic effects like drought, lightning strike, branches broken in a storm, lack of nutrients, etc.);
b.**Biotic** (diseases, insects and other pests, fungi, browsing by camels or goats, etc.);
c.**Anthropogenic** (caused by humans: stem damage with machines, bad pruning, etc.);
d.**Unknown;**

11.**Additional data:** The height of a tree is measured from the foot to the highest point in the centre of the tree axis of every fifth tree.

1. **Location: Serapium Forest, Ismailia** 2. **Date: …../…../…………** 3. **Plot N°** ☐ **- F3 – a1**

4. **Coordinates: E: N:** 5. **Plot size…….m x ……m**

6. **Distance of rows: ………..; Distance of trees in row: ……….** 7. **Planting period** (mm/yyyy)**: ……/…………**

8. **Team members: ……………………………………………………………………………………………………**

9. **IRRIGATION TIMING: scheduled…………………hours/day; current…………………hours/day**

		Species name	*Minimum data*								[11]*Additional data*
Position N°[1]	Tree N°[2]	Scientific name / Common (local) name	Dbh[3]	Commercial (Bole) Height[4]	Vitality[5]	Tree Quality[6]	Social class[7]	Stem form[8]	Damage degree[9]	Damage type[10]	Total Height[11]
			cm	m	C	C	C	C	C	C	m

[1]**Position No** Position of tree growth. Several trees can grow at the same spot; [2]**Tree No** Number of the measured tree; [3]**Diameter at breast height** 1.30m	[4]**Commercial (Bole) height** Tree height from foot to: a)the first big branch where bole quality decreases reasonably; b)fork; c)minimum diameter 5cm; If fork <1.30m measure boles from fork to a, b or c.	[5]**Vitality (Crown condition)** **1 Healthy** (densely foliated, no top dieback); **2 Moderate health** (fairly foliated, top dieback); **3 Unhealthy** (poorly foliated, severe top dieback); **4 Dead**	[6]**Tree Quality** **1 High** (straight trunk, free of fork, well formed crown, no defects); **2 Satisfactory** (slightly crooked, slightly forked, fairly formed crown, little defects); **3 Low** (sharply crooked, strongly forked, badly formed crown severe defects); **4 Shrubby**;	[7]**Social class** **1** Dominant; **2** Co – dominant; **3** Intermediate; **4** Overtopped; **5** Totally suppressed;
[8]**Stem form** **1** Straight; **2** Slightly crooked; **3** Strongly crooked;	[9]**Damage degree** **1** undamaged/healthy; **2** slightly affected; **3** severely affected;	[10]**Damage type** **1** abiotic; **2** biotic; **3** anthropogenic; 4 unknown;	[11]**Additional data** Every 5th tree; if the 5th tree is dead, missing or severely damaged in the crown than measure the next following tree.	

Figure 6: Field form F3-a1 (FAO-NFMA, adjusted)

1. **Location: Serapium Forest Ismailia** 2. **Plot N°** ☐ **- F3 – a2**

Stand description[1]:

Stand type [(1;2)]:

Dominant tree species (>95%): ....

Numerous trees (<5%): .... Several trees (1-5%): ....

Single trees (1%): ....

Tree canopy cover [(6)]: ☐ Dense/Interlocking ☐ Closed ☐ Slightly closed
☐ Scattered ☐ Discontinuous ☐ Wide open

Health condition and vitality [(9)]:

Pests and diseases: ☐ Foliage pests: ☐ Galls ☐ Leave miner ☐ Necrosis ☐ Other: ....
☐ Bark diseases: ☐ Bark beetles ☐ Other: ....
☐ Fungi
☐ Other: ....
Remarks: ....
....

Physical damage: ☐ Root ☐ Trunk ☐ Crown
Remarks: ....
....

Other characteristics [(13)]:

Ground vegetation: ☐ Herbaceous ☐ Shrubs
☐ (Sparse) 0-30% ☐ (Medium) 31-70% ☐ (Dense) > 70%
Species: ....

Litter thickness: ☐ absent ☐ 1-5cm ☐ 6-10cm ☐ >10cm

Other observations: ....

Previous treatments [(14)]:

Thinning: ☐ no ☐ 1st ☐ 2nd Remarks: ....

Pruning: ☐ no ☐ yes ☐ Remarks: ....

Replanting: ☐ no ☐ yes ☐ New Species.............................. Remarks: ....

Other: ....

Irrigation system: ☐ OK ☐ Problems Remarks: ....

Management suggestions [(16)]:

☐ Repair the irrigation system
☐ Substitute current species (with the species ....)
☐ Pruning
☐ Thinning
☐ Replant failed individuals (with the species ....)
☐ Other: ....

Notes:

....
....
....
....
....
....
....

[1] Selection of a complete stand description according to the list in the field manual.

Figure 7: Field form F3-a2 (stand description parameters)

Data analysis methodology

In September 2012 a forest inventory was carried out at the Serapium forest plantation with the objective to detect the growing stock of the plantation and the general conditions of the stands. As requested by the Undersecretariat for Afforestation, this was also an opportunity to provide training to seven national forestry experts, representing the most important Egyptian forestry institutions. The inventory and the related "*Integrated forest inventory training"* focused primarily on tree species, since planted non-tree species only cover 10% of the total forest area and they will soon be replaced by other tree-species in the coming years.

Definition of Growing stock

"Volume over bark of all living trees more than X cm in diameter at breast height (DBH). Includes the stem from ground level or stump height up to a top diameter of Y cm, and may also include branches up to a minimum diameter of W cm" (FAO 2010b: 212).

For the purpose of this inventory trees with a DBH >5 cm have been measured over bark. Only in very young stands (Eucalyptus citriodora) trees with DBH >3cm have been measured. If bigger branches are included in the volume over bark of one species is defined below. Smaller branches, twigs, foliage, flowers, seeds and roots are generally excluded from volume calculations (above ground).

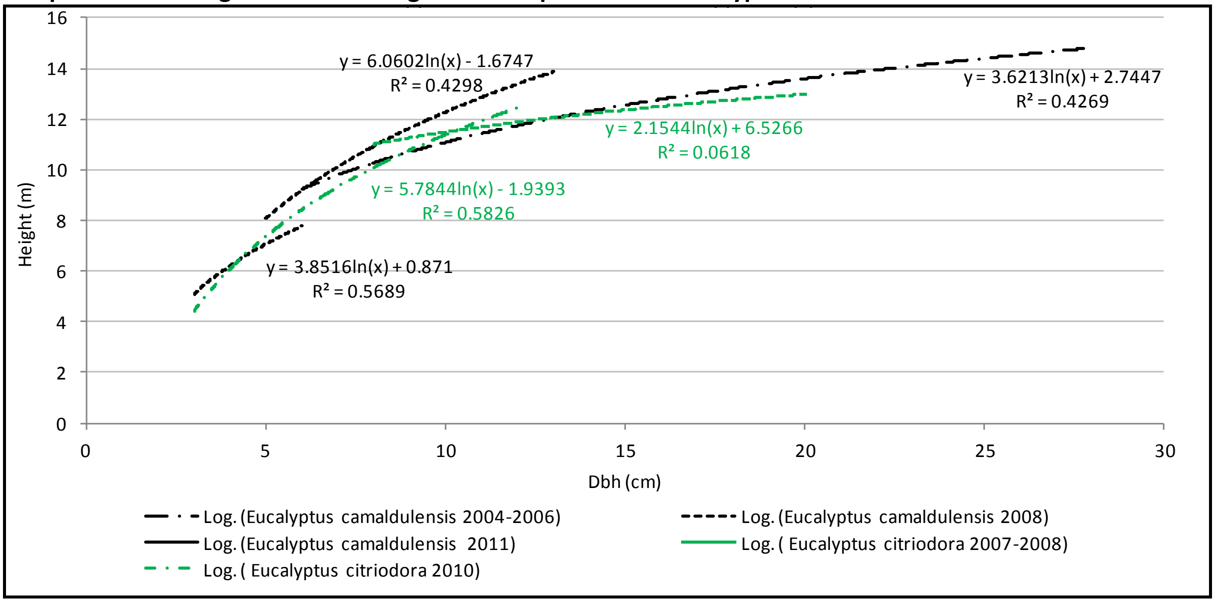
The following parameters were recorded and measured in every sample plot, using a field form (F3-a1) which was adapted from the FAO National Forest Monitoring and Assessment (NFMA) field form. These were: tree position, tree number, scientific name/local name and the *minimum data* (year of planting, dbh, commercial height, stem quality, vitality, social class, damage degree, damage type). Total tree height was taken every five measured trees. The general situation of the stand for every sample plot was described in a second field form (F3-a2). For more detailed information on the data collection and the procedure followed, please refer to the *Manual for Integrated Field Data Collection* herewith attached. The data and the information collected were inserted in a Microsoft Access database based on the NFMA Access database and which was specifically customized for this inventory. The data collected in the field form F3-a1 were elaborated to represent the stands per tree species and per years, using Microsoft Excel software. To analyze and review all the processes, preference was given to the use of Excel rather than Access, because of its easiness to use and more familiarity with the training participants. In the Excel software all the statistical analyses were programmed to reduce manual errors. The planting year of the parcels was provided by the plantation manager.

The main steps of data analysis are described in the following:

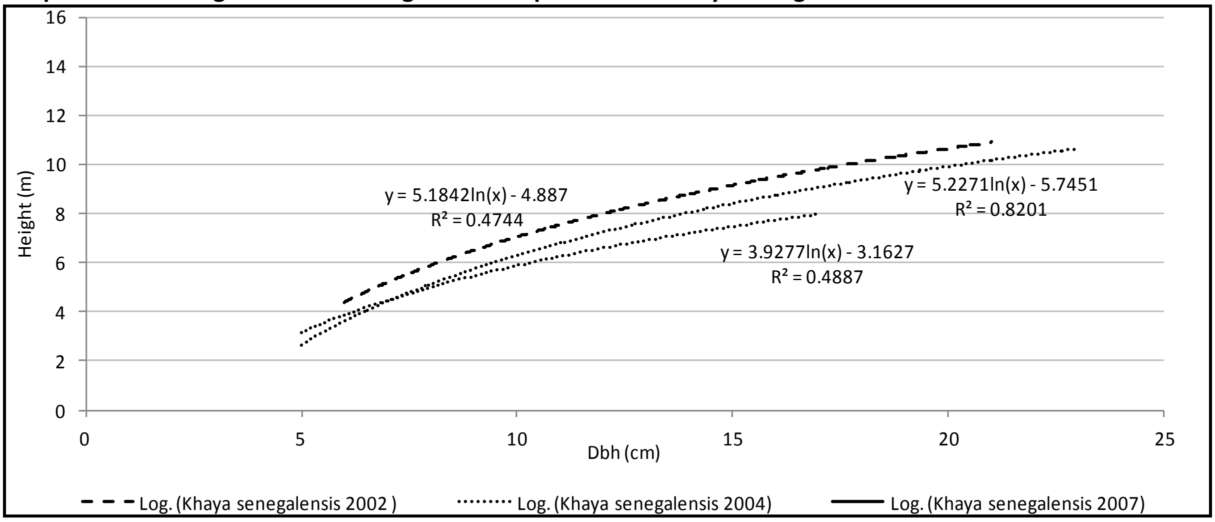
1. The data collected in the field form data F3-a1 were copied in an *ad hoc* prepared Excel sheet.
2. The DBH-height-curves were calculated for each tree species and age (logarithmic function using assessed data of single trees).

For each species and age, the tree heights measured in the sample plots were put in relation with the corresponding measured DBH of the tree through a logarithmic function. The calculated curves for the tree species and age classes at Serapium forest can be seen in the following.

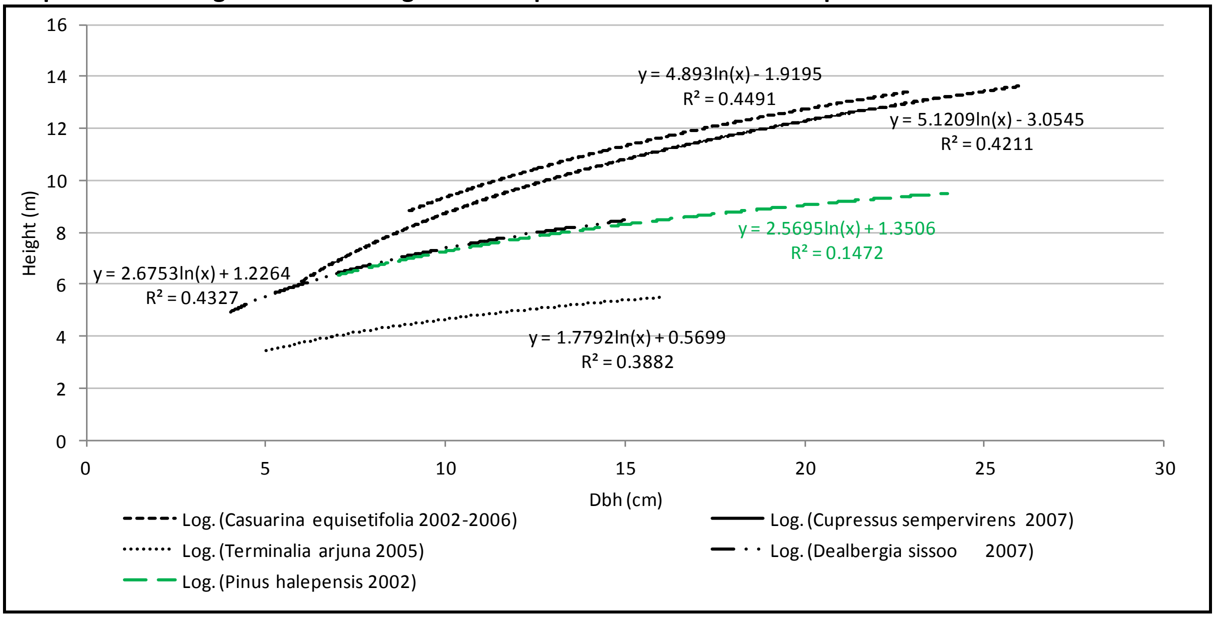
Graphic 1: DBH-height curves and logarithmic equations for Eucalyptus camaldulensis and E. citriodora.



Graphic 2: DBH-height curves and logarithmic equations for Khaya senegalensis.



Graphic 3: DBH-height curves and logarithmic equations of different tree species



The logarithmic equations were used to calculate the height of the trees based on the measured DBH. The calculated equations show a relatively low correlation (R^2) between DBH and height.

3. Basic dendrometric parameters have been calculated per each sample plot.
   The dendrometric parameters were referred to ha and feddan in order to compare them.
   The main parameters calculated were:
   - Density of trees.
   - Total Basal Area (BA).

$$BA = \frac{\pi}{4} dbh_1^{\ 2} + \frac{\pi}{4} dbh_2^{\ 2} + \frac{\pi}{4} dbh_3^{\ 2} + \cdots . + \frac{\pi}{4} dbh_n^{\ 2}$$

π = 3.1415...
dbh = diameter at breast height

   - Medium dbh ($\overline{dbh}$) (medium dbh of the medium basal area).

$$\overline{dbh} = \sqrt{\frac{4\overline{BA}}{\pi}}; \ \overline{BA} = \frac{BA}{N}; \ BA = \frac{\pi}{4} x\ dbh^2$$

   - Total tree height (h - see above) and height of the commercial bole.
   - Other useful parameters for the description of the stand (stem quality, vitality, social class, damage degree, damage type).

4. Growing stock (GS - volume of the stand) has been calculated for each species and stratum.

The volume of a given stand can be calculated through the use of allometric equations or form factors for each of the species planted. Both equations and form factors can only be calculated by felling a number of trees to statistically represent each species. Given the relatively short time available for the forest inventory and considering the high environmental value of each planted tree in such a difficult environment, it was decided to fell only few trees and to carry out literature research to find allometric equations or form factors for the different species planted in similar ecological conditions (eco-region, irrigation, density, stand establishment).

Allometric equations always provide above ground biomass which mostly refer to the volume of the treetop, branches and the stump. In order to calculate the commercial volume from an allometric equation the results have to be reduced by an estimated 20% harvesting loss.

$$GS = \sum_{n}^{1} V_1 + V_2 + V_3 + \cdots + V_n$$

Table 7- Tree components comprised in volume equations per species.

Volume equations	
Tree components comprised in the volume equations	**Tree species**
Stem over bark	Casuarina equisetifolia, Dalbergia sissoo, Pinus halepensis
Stem over bark + Branches	Cupressus sempervirens, Eucalyptus camaldulensis, Eucalyptus citriodora, Khaya senegalensis, Terminalia arjuna
Commercial bole over bark	Khaya senegalensis

Equations and / or form factors used for each species are the following:

–**Casuarina equisetifolia** → Form factor (*f*) = 0.39 (El-Osta et al. 1992: 65).

Form factor used to calculate the stem volume over bark (m^3).

$$V = BA * h_{tot} * f$$

BA= basal area
h_{tot} = total tree height/length
f= form factor

–**Cupressus sempervirens** → allometric equation (Tabacchi et al. 2011: 47).

The equation calculates stem volume over bark up to 5 cm at the top and up to 5 cm of the braches. It has been estimated that this equation corresponds to a form factor approximately equal to 0.50.

$$V = -2.6735 + 3.659 * 10^{-2} * dbh^2 * h_{tot} + 6.4725 * 10^{-1} * dbh$$

V[dm^3]; dbh[cm]; h[m]

–**Dalbergia sissoo** → Form factor (*f*) = 0.5.

Form factor for stem volume over bark (m^3). No equation or form factor was found for this species in comparable conditions, therefore a medium form factor for broadleaved trees species was used (FAO, 2011b: 84).

$$V = BA * h_{tot} * f$$

–**Eucalyptus camaldulensis** → Form factor (*f*) = 0.52 (FAO 1981: 530, 532).

Form factor for stem volume over bark and branches up to 3 cm (m^3).

$$V = BA * h_{tot} * f$$

–**Eucalyptus citriodora** → Form factor (*f*) = 0.52 (FAO 1981: 530, 532).

Form factor for stem volume over bark and branches up to 3 cm (m^3).

$$V = BA * h_{tot} * f$$

–**Khaya senegalensis** → Allometric equation (Clément 1982).

The equation calculates stem volume over bark, including big and thin branches (m^3). This equation corresponds to a form factor approximately equal to 0.77.

$$V = -0.00537 + 0.06233 * C + 0.54878 * C^2$$

C = Circumference at breast height over bark
V[m^3], C[m]

–**Khaya senegalensis** → Form factor commercial bole (*f*) = 1.08 (Field inventory).

Form factor for commercial bole volume over bark (m^3). During the field inventory diameters at different heights were measured for nine trees of Khaya senegalensis to calculate the form factor of the commercial bole (see the definition in the *Manual for Integrated Field Data Collection*). The trees were planted in 2002 but belonged to different diameter classes to represent the variability of the stand. Considering the limited sample measured, the parameter is still approximated to represent the population of Khaya in the plantation. The resulting form factor is so high because the commercial bole of this species is very short and often corresponds to 1/4 of the total height.

$$V = BA * h_{commercial\ bole} * f$$

$h_{commercial\ bole}$ = Height of the commercial bole

–**Pinus halepensis** → Form factor (*f*) = 0.65.

Form factor for stem volume over bark (m^3). No equation or form factor was found for this species in similar conditions, therefore an average form factor for conifers was used (FAO 2011b: 84).

$$V = BA * h_{tot} * f$$

–**Terminalia arjuna** → Allometric equation (Nouvellet 2002).

The equation calculates stem volume over bark (m^3), including big branches up to 7 cm and the stump up to 10-20 cm. The equation corresponds to an estimated form factor of 0.56.

$$V = -0.01564 + 0.13174\ x\ C + 0.57929\ x\ C^3$$

C = Circumference at breast height over bark
$V[m^3]$, $C[m]$

5. The dendrometric parameters per sample plot and stratum were calculated to hectare values.

Inventory results (tree species)

Table 8 gives the main dendrometric parameters of the tree species. The potential average tree density is 1111 trees/ha, deriving from the planting distance of 3m x 3m. Deviations from the theoretical density show that trees are missing on planting positions, which is one proof that the full potential of the parcels is not used. The missing of trees is mainly caused by high mortality rates of the trees (damaged by drought or browsing) (e.g. *Cupressus sempervirens* 2002 or *Khaya senegalensis* 2004). In some stands the removal of trees during thinning operations (e.g. *Eucalyptus camaldulensis* 2004) reduced the density. In the case of *Casuarina equisetifolia* 2006 a thinning operation reduced stems to less than 50%. Plant density remains high because remaining stumps have grown shoots and the plants were categorized as shrubby. A higher tree density than 1111trees/ha is a sign that two or more trees are growing at the same planting position. This can be induced by coppice or by planting more than one seedling at the same position.

The percentage of missing, shrubby or dead trees is in general very high and ranges from 10% to 51%. In few Eucalyptus stands the high percentage of shrubby plants is induced by coppice operations. In the majority of the stands plant mortality is the problem. It is also a sign that replanting of failed individuals did not take place in the first year after stand establishment.

The commercial height of the trees is mostly less than ½ of the tree height or even less than $^{1}/_{3}$ of the total tree height over all tree species. Stems are either crooked or damaged in a low part or low thick branches reduce bole quality.

Mean annual increment ranges from 3.8 m^3/ha/year to 11.7 m^3/ha/year. Best increments show *Eucalyptus camaldulensis*, *Eucalyptus citriodora* and *Khaya senegalensis*. *Cupressus sempervirens* has high growing stock, but lower increment (6.4 m^3/ha/year). Highest volume per hectare shows *Khaya senegalensis* from 2002 (102.5 m^3/ha). Also volume per hectare of *Eucalyptus camaldulensis* and *Pinus halepensis* are reasonable and can be compared, in the case of *Eucalyptus*, with yield values of plantations in Portugal, Morocco and other north African countries (FAO 1981: 304ff, 535ff). The variation of increment between different ages of the same species (as visualized in graphic 4) can be natural, but it is more likely that it derives from difficult site conditions and the irregular provision of water in different parts of the plantation. It is therefore difficult to predict the real increment and growing stock values.

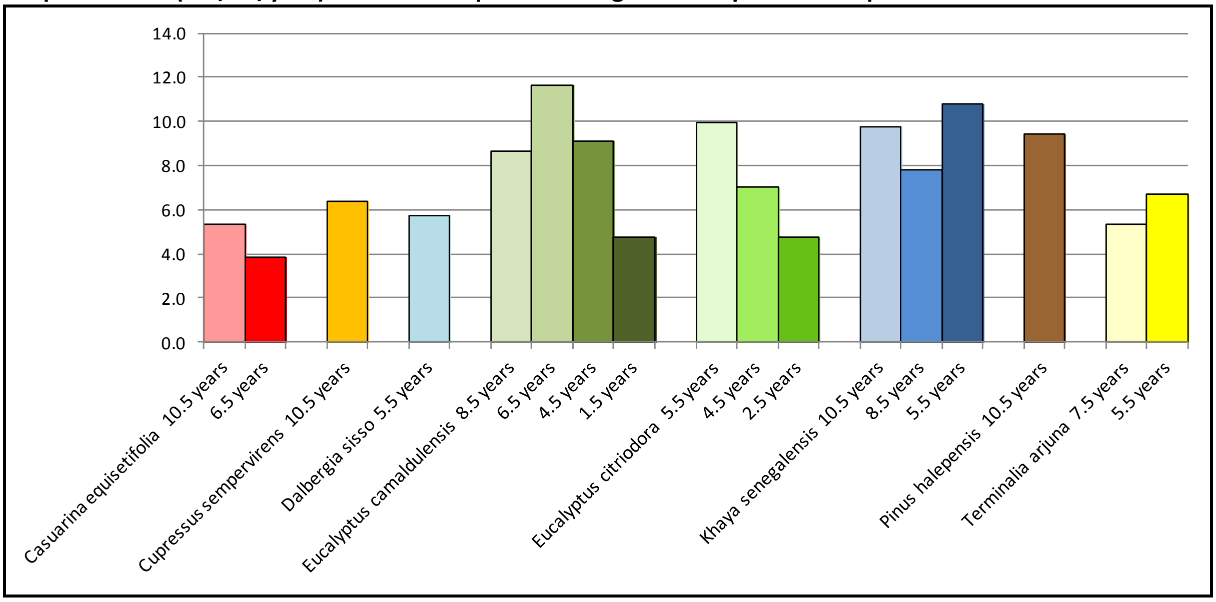
Current growing stock totals up to 4380 m^3 at which *Cupressus sempervirens* and *Khaya senegalensis* have highest share. Growing stock averages over the area of the assessed species to 54.4 m^3/ha.

Table 8 and graphic 4 are followed by the description of quality parameters and a brief summary of the status of each species at Serapium forest.

Table 8: Dendrometric parameters at the Serapium forest plantation.

Main species	Planting year	Age (years)	Area (ha)	Trees/ha	Trees missing/ shrubby/ dead (%)	Basal area (m^2/ha)	Mean Dbh (cm)	Mean tree height (m)	Mean commercial height (m)	Solid wood volume per ha (m3/ha)	Mean annual volume increment, MAI (m^3/ha/year)	Growing stock (GS) (m^3)	Volume commercial bole (m^3)
Casuarina equisetifolia	01/3/2002	10.7	1.7	998	27	12.9	13.3	10.7	4.4	56.0	5.3	97.3	
	01/3/2006	6.7	1.6	1066	52	6.3	8.7	8.7	4.1	25.0	3.7	40.3	
Cupressus sempervirens	01/3/2002	10.7	20.7	893	41	12.2	13.5	10.2	4.2	66.7	6.3	1379.2	
Dalbergia sisso	01/3/2007	5.7	2.5	1054	14	8.3	10.0	7.4	2.6	31.7	5.6	80.3	
Eucalyptus camaldulensis	01/3/2004	8.7	0.6	522	82	10.3	15.9	12.8	4.7	73.3	8.5	44.5	
	01/3/2006	6.7	1.5	1542	10	12.5	10.2	11.1	4.7	75.7	11.4	110.7	
	01/3/2008	4.7	2.8	1406	27	6.8	8.0	10.9	3.9	41.0	8.8	116.3	
	01/3/2011	1.7	2.1	2041	36	2.2	3.8	6.0	2.2	7.2	4.3	15.2	
Eucalyptus citriodora	01/3/2007	5.7	1.6	1111	29	9.1	10.3	11.6	4.7	54.8	9.7	86.7	
	01/3/2008	4.7	5.0	779	51	5.3	8.8	10.3	4.4	31.6	6.8	159.0	
	01/3/2010	2.7	9.5	1173	40	2.6	5.0	7.1	3.0	11.9	4.5	113.5	
Khaya senegalensis	01/3/2002	10.7	5.6	958	32	12.4	12.9	8.3	2.3	102.5	9.6	569.8	191.5
	01/3/2004	8.7	6.1	839	51	7.9	11.3	6.8	2.1	66.5	7.7	408.8	125.9
	01/3/2007	5.7	13.3	907	48	7.0	10.5	6.1	1.8	59.4	10.5	791.1	198.4
Pinus halepensis	01/3/2002	10.7	2.5	1077	30	17.8	15.0	8.3	3.0	99.2	9.3	245.3	
Terminalia arjuna	01/3/2005	7.7	1.9	952	27	7.2	9.8	4.6		40.0	5.2	74.7	
	01/3/2007	5.7	1.6	1315	59	7.0	8.2	4.3		37.0	6.5	60.7	
Total or Average		6.9	**80.7**	1096	39	8.7	10.3	8.5	3.5	51.7	7.3	**4393.4**	
												54.4	

Graphic 4: MAI (m3/ha/year) of different species and ages at Serapium forest plantation.



Casuarina equisetifolia

Table 9: Assessed tree quality parameters Casuarina equisetifolia

Planting year	Age (years)	Mean vitality	Mean tree quality	Mean social class	Mean stem form	Mean damage degree	Damage type
01/3/2002	10.5	Moderate health	Satisfactory	Co-dominant	Slightly crooked	Undamaged /healthy	Abiotic
01/3/2006	6.5	Healthy	Low	Intermediate	Slightly crooked	Undamaged /healthy	Biotic

This is a successful tree species, well adapted to site conditions, generally healthy (planted in 2006) or of moderate health (planted in 2002). It has an average growth of 5 m^3/ha/year, but in optimal climate conditions can reach 15 m^3/ha/year (CABI 2012a). The parcels of 2006 were thinned and pruned in 2010. The thinning was carried out following a regular schema (every second tree) and it was not deemed necessary to decrease the density to reduce competition in the crowns. The pruning was not properly done (branches cut off too far from the trunk) and not focused on quality of trees. Pruning caused more damage than actually improving the quality of the tree, but overall this was not reflected in the damage assessment since trees remained healthy. Total percentage of missing, shrubby or dead trees is mainly due to the thinning, therefore it is not relevant. In the 2002 parcels the crown closure is dense. Straight stems are very rare.

When cultivated Casuarina equisetifolia will thrive in a wider range of rainfall, from less than 350 mm to 5000 mm per annum as described by PINYOPUSARERK & HOUSE (1993) (CABI 2012a). C. equisetifolia is a nitrogen-fixing tree. It is relatively fast-growing on poor soils and tolerates salt-laden winds. It can also be successfully used as windbreak (CABI 2012a).

Cupressus sempervirens

Table 10: Assessed tree quality parameters Cupressus sempervirens

Planting year	Age (years)	Mean vitality	Mean tree quality	Mean social class	Mean stem form	Mean damage degree	Damage type
01/3/2002	10.5	Moderate health	Satisfactory	Intermediate	Slightly crooked	Slightly affected	Anthropogenic

Although the Cupressus sempervirens was retained in the plantation for the past ten years, it must be regarded as an unsuccessful species. It heavily suffered drought and the percentage of dead, missing and shrubby trees equal to 41% of the total trees. It scores “moderate health” for its mean vitality, but this needs to be considered as a generous rating. The more stressed plants are starting to be attacked by bark beetles and die. Stem quality is slightly crooked and the stem is not free of branches, as common for other Cupressus. The tree density is reduced by the dieback of individual trees and is not due to any thinning operations. Given the planting distance, there is no crown closure. The damages result from some pruning trials.

Dalbergia sissoo

Table 11: Assessed tree quality parameters Dalbergia sissoo

Planting year	Age (years)	Mean vitality	Mean tree quality	Mean social class	Mean stem form	Mean damage degree	Damage type
01/3/2007	5.5	Healthy	Low	Intermediate	Slightly crooked	Undamaged/ healthy	Anthropogenic

This tree species has relatively well adapted to site conditions. It is quite healthy but displays a general low quality, due to effects of the heavy browsing of camels when plants were smaller. The medium volume increment per year equals to 6m^3/ha/year.

Eucalyptus camaldulensis

Table 12: Assessed tree quality parameters Eucalyptus camaldulensis

Planting year	Age (years)	Mean vitality	Mean tree quality	Mean social class	Mean stem form	Mean damage degree	Damage type
01/3/2004	8.5	Healthy	Low	Intermediate	Slightly crooked	Slightly affected	Biotic
01/3/2006	6.5	Healthy	Low	Intermediate	Slightly crooked	Undamaged/ healthy	Anthropogenic
01/3/2008	4.5	Moderate health	Low	Intermediate	Slightly crooked	Undamaged/ healthy	Anthropogenic
01/3/2011	1.5	Moderate health	Satisfa ctory	Intermediate	Slightly crooked	Undamaged/ healthy	Abiotic

Eucalyptus camaldulensis is a successful tree species at Serapium, which presents good growth (9m^3/ha/year) and a quite good adaptability to site conditions. The average quality is generally low because of lack or inappropriate silvicultural practices (missed thinning and inadequate pruning techniques). E. camaldulensis seedlings are attacked by galls which deform the stem and reduce the future quality of the trunk. Hence adult trees are not damaged by galls. From the year 2004 trees have been removed from the parcels due to dieback or other damages (dieback may be caused by insufficient water supply), so the high percentage of missing, shrubby and dead trees in table 8 mainly derives from the thinning operations. Stem are slightly crooked and even higher quality boles are not completely free of branches.

The mean annual rainfall for E. camaldulensis is in its natural range 250-600 mm, although a few areas receive up to 1250 mm and some as little as 150 mm (CABI 2012b). Keys to the success of E. camaldulensis are its superiority, compared to other trees, in the production of wood on unproductive dry land, its tolerance to extreme drought and high temperature, combined with rapid growth rate when water is available (GIBSON et al. 1995 in CABI 2012b). In the dryer tropics, yields of 5-10 cubic meters/ha/yr, over 10-20 year rotations, are common, whereas in more humid regions up to 30m^3/ha/year may be achieved on 7-20 year rotations (EVANS 1992).

Eucalyptus citriodora

Table 13: Assessed tree quality parameters Eucalyptus citriodora

Planting year	Age (years)	Mean vitality	Mean tree quality	Mean social class	Mean stem form	Mean damage degree	Damage type
01/3/2007	5.5	Healthy	Satisfactory	Intermediate	Slightly crooked	Undamaged/ healthy	-
01/3/2008	4.5	Healthy	Satisfactory	Intermediate	Straight	Undamaged/ healthy	Anthropogenic
01/3/2010	2.5	Healthy	Low	Intermediate	Slightly crooked	Undamaged/ healthy	-

This is one of the most successful tree species in the plantation. E. citriodora showed a good growth rate (7 m^3/ha/year), also considering the site's conditions, but this is moderate when compared to the literature. It displays good adaptability and no particular problems with pests and diseases. The average quality of the tree is generally satisfactory but could be improved with the correct silvicultural practices (tending and thinning). As detected in parcel 147, E. citriodora does not tolerate compact soils. The stem is predominantly slightly crooked and even higher quality boles are not completely free of branches, although E. citriodora is tending to self pruning. As a young plant it shows enormous growth and it is able to reach 3-4 m(estimated) in the first 2 years after planting.

In general this is a handsome tree of excellent form, with a well-shaped but sparsely foliaged crown. It can easily adapt, it is drought tolerant and capable of reasonable growth rates in both summer and winter rainfall areas. For the purpose of cultivation, this is by far one of the best species of eucalypts, especially at the lower latitudes of the subtropics and tropics, but not so in equatorial regions (FAO 1981). It can survive light frosts. A minimum annual rainfall of 600 mm is generally required for E. citriodora, for rapid growth a rainfall of 900 mm is desirable (CABI 2012c). The species produces strong, hard and moderately durable wood, suitable for fuel wood, charcoal, posts and poles, household products, tool handles, sawn timber and general construction materials (CABI 2012c). Mean annual increments (MAIs) in wood production of 12-15 m^3/hectare have been recorded in Africa, China and Brazil (AYLING & MARTINS (1981) and RICHARDSON (1990) in CABI 2012c).

Khaya grandifoliola

The only parcel with such species is in critical condition. For the purpose of the inventory, the trees of Khaya grandifoliola were considered as dead.

Khaya senegalensis

Table 14: Assessed tree quality parameters Khaya senegalensis

Planting year	Age (years)	Mean vitality	Mean tree quality	Mean social class	Mean stem form	Mean damage degree	Damage type
01/3/2002	12	Moderate health	Low	Intermediate	Slightly crooked	Slightly affected	Biotic
01/3/2004	8	Moderate health	Low	Intermediate	Slightly crooked	Slightly affected	Anthropogenic
01/3/2007	7	Moderate health	Low	Intermediate	Slightly crooked	Slightly affected	Biotic

Khaya s. exhibits a good growth of 10 m^3/ha/year, compared to an estimated medium value of 3.7 m3/ha/year in Burkina Faso in 1971 (CABI 2012d). Despite the significant growth rate achieved in well irrigated parcels, the species is particularly sensitive to drought and shows moderate to lower health conditions where the irrigation fails. In the external parts of the parcels this species is particularly suffering due to the distance from the main pipes, and therefore decreasing water supply. The tree quality is generally low because of the general stressing conditions and the lack of proper silvicultural practices (no tending operation on young plants and lack of thinning). The commercial bole is very short, with an average length of 2 m which corresponds to only 1/3 of the total height. The short commercial bole may be the result of an attack of a shoot borer in young stands (which leads to a low position of the crown), or omitted tending operations in the young stands and or omitted selection processes during thinning operations. The crown closure is dense to densely interlocking and therefore the crowns often do not regularly develop. The average stem form is slightly crooked and no high quality trees were detected that would fulfill the requirements for veneers. Pruning often triggered sprouts and the development of branches where the tree was injured, so no quality improvement was achieved. Pruning was usually carried out at a too late stage.

The main geographical distribution of Khaya senegalensis corresponds to the climatic zone of Sudan, characterized by an annual precipitation of 650-1300 mm during summer and an annual mean temperature of about 24°C. The tolerated lower limit of the annual mean temperature is about 22°C (CABI 2012d). Khaya senegalensis is generally a light-demanding species (although it will tolerate up to 50% shade when immature), and one of the most drought-tolerant Khaya species but it is susceptible to fire in the early age. Although it grows best on deep, fertile soils, savannas and rocky sites, it will tolerate dry or lateritic soils. The species is particularly valued for timber and for fuel wood.

Pinus halepensis

Table 15: Assessed tree quality parameters Pinus halepensis

Planting year	Age (years)	Mean vitality	Mean trees quality	Mean social class	Mean stem form	Mean damage degree	Mode of damage type
01/3/2002	10.5	Moderate health	Low	Intermediate	Strongly crooked	-	-

This is an unsuccessful species at Serapium regarding its quality. Plants seem not to be exceedingly stressed by drought. Nevertheless the remaining parcels present a high percentage of dead, missing or shrubby trees (30% of the total trees). The trees in the remaining parcels are moderate in health and are generally of low quality, with strongly crooked stems. The trees have been pruned despite the impossibility to use them as valuable wood. UAE and the plantation management already decided to replace this species and stopped maintenance except in few parcels. Forest experts from TUM assume that the low quality derives from insufficiently proofed origin of the seed material. Although aleppo pine is a drought-tolerant, fast growing conifer with a wide range of use it is seldom used for commercial forestry anywhere in the world, mainly because of its poor stem form and low-quality timber (CABI 2012e).

Terminalia arjuna

Table 16: Assessed tree quality parameters Terminalia arjuna

Planting year	Age (years)	Mean vitality	Mean tree quality	Mean social class	Mean stem form	Mean damage degree	Damage type
01/3/2005	7.5	Healthy	-	-	-	-	-
01/3/2007	5.5	Healthy	-	-	-	-	-

It is a tree species that grows in some multi-stemmed parcels. It has well adapted to the site conditions, healthy but usually of a low quality. The medium volume increment per year is $6m^3$/ha/year.

Non-tree species

Following the irrigation system, non-tree species as well as trees species, have a standard density of 1111 plants/ha, with a planting distance of 3m x 3m. For non-tree species no sample data was collected, considering their irrelevance compared to tree species, which are ultimately the main concern of this management plan. The species present in the plantation are briefly described below:

Bambus spp.: It has been planted in 2007 as an experimental species. It is still irrigated and maintained.

Jatropha curcas: Planted in 2006 and 2010 as experimental species. Still irrigated and in place.

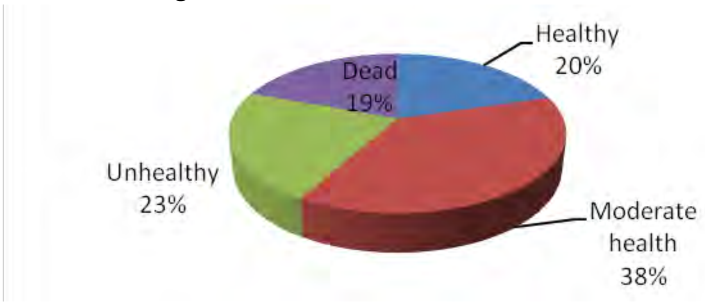
Jojoba (Simmondsia chinensis): Planted in 2010 as another experimental species. It is still irrigated and maintained.

Sisal (Agave sisalana): Planted in 2002 for fiber production. Growth was quite reasonable, but the quantity was not enough to supply market demands. In the last year irrigation was stopped and the plants die.

Pests and diseases

For future silvicultural planning it is important to assess the health situation of the regeneration plantings. Casuarina equisetifolia, Eucalyptus citriodora and Eucalyptus camaldulensis have been recently planted in 2011 and 2012. It was observed that young stands of Eucalyptus camaldulensis are more vulnerable to attacks from pests and diseases or to damage by browsing than other species. The situation was assessed with two sample plots in the area of E. camaldulensis from the year 2012. The sample plots were randomly selected according to the sample design for the forest inventory. The following parameters of the seedlings were assessed: trees per ha, vitality, presence and type of damage, pest or disease (symptoms), level of the damage, affected parts of the seedling.

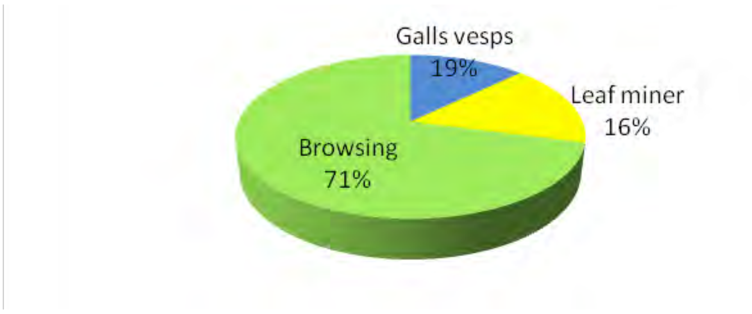
The analysis shows that only 20% of the seedlings are healthy, 23% are unhealthy, 38% show moderate health and 19% are dead. Young plants are more vulnerable to drought than older plants and the shortage of water caused by the breaking up of the pumping system exacerbates the overall status of the seedlings.



Graphic 5: Vitality of regeneration plantings of Eucalyptus camaldulensis.

The rate of damage is alarmingly high. The assessment shows that 59% of the seedlings are damaged. The damage degree at the seedlings varies: 65% of the damaged seedlings show a high degree of damage, 32% show medium damages, and only 3% show a low degree of damage.

The most heavily damaged trees are mainly affected by animal browsing (71%), by galls wasps (19%) or by leaf miners (16%). Browsing is a particularly relevant problem for young stands.



Graphic 6: Causes of damages of the trees damaged in the young stands of Eucalyptus camaldulensis.

Eucalyptus citriodora is not affected by browsing. Except from occasional gum flow on some stems Eucalyptus citriodora shows at the moment no signs of pests and diseases. Khaya senegalensis is browsed heavily and regeneration plantings with this species are not recommended. The possible attack of a shoot borer on this tree species must be investigated. Dalbergia is browsed and was attacked by a caterpillar in June 2012 that damaged the leaves to 100%. Luckily the trees recovered. Cupressus sempervirens is attacked by a bark beetle when the trees are weakened by drought stress.

Negative future effects of damaged seedlings are various. Damage on the main shoot of a tree plant reduces growth and determines the later tree quality. The loss of seedlings reduces the number of potential crop trees, which provokes a reduction of the commercial volume. Each dead seedling is a tree that cannot be sold.

Socio-economic framework

Stakeholders and partnerships

The results in this chapter are based on a workshop held during the "Integrated Forest Inventory Training" and reflect the experiences from the plantation manager and the discussions among the participants. Figure 8 shows an overview of the identified stakeholders of the Serapium forest plantation from the public and the private sector. Stakeholders highlighted in red are involved in problems and threats that are considered as highly problematic. The degree of the potential influence on the plantation is indicated by the thickness of the arrow. The complete overview of the stakeholder assessment is in the annex. There the linkages between the described conflicts and threats are clearly visible.

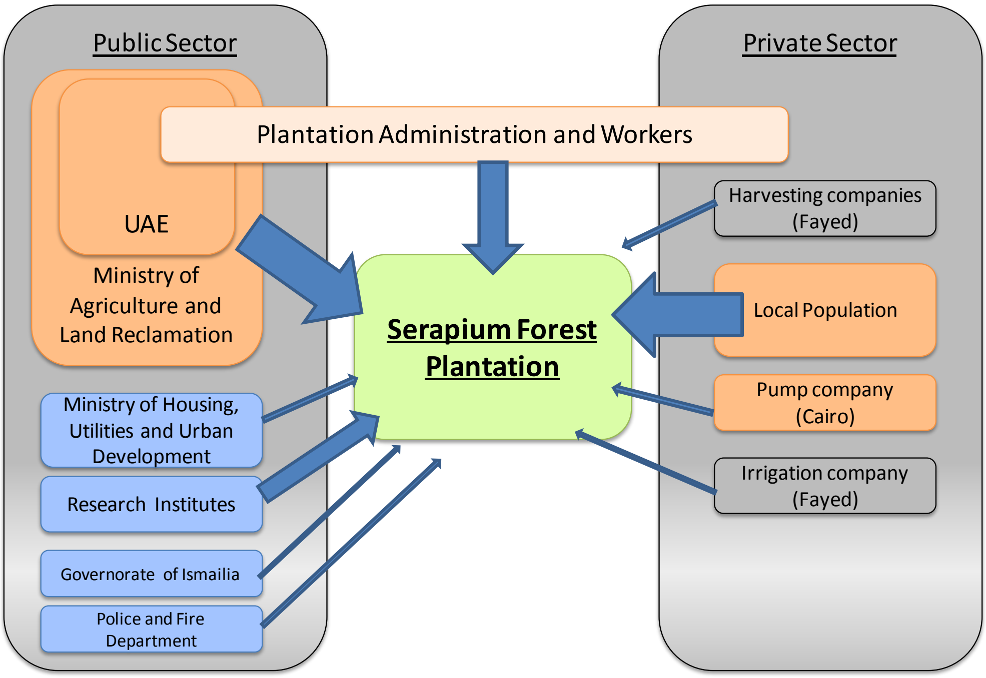


Figure 8: Influence of stakeholders from public and private sector on the Serapium forest plantation

Public sector: The Ministry of Agriculture and Land Reclamation is the official owner of the Serapium forest plantation. The Undersecretariat for Afforestation, as part of the ministry and at the plantation represented through the plantation manager (plantation administration), is responsible for the management of the plantation. The Ministry of Housing, Utilities and Urban Development is the owner of the TWW facilities and provides the plantation with the required quantities of TWW for the irrigation in the framework of the NPTWWA. National research institutes support the UAE and the plantation management with scientific knowledge and guidance for species selection trials. International cooperation is manifold (FAO, United States Agency for International Development USAID, TUM, etc.) Guidance in implementing silvicultural techniques is missing either from national or international side. The plantation is located in the governorate of Ismailia, which political institutions are therefore responsible for the provision of general infrastructure services like electricity and potable water.

Private sector: Whereas the plantation management belongs to the UAE and the public sector, the workers, as employees, are more considered as part of the private sectors. The UAE and the plantation management interact with various private companies. Harvesting and wood buying companies/ entrepreneurs are mainly located in nearby villages (Fayed). A company, which is specialized on irrigation systems, is hired on demand for the extension or repair of the tubes. The company that has the technical skills to maintain and repair the big electric pumps is located in Cairo. The local population (informally called “Badus”) that lives in the direct surrounding of the plantation is a very heterogeneous group of estimated 200 – 300 people who are not officially organized. Parts of this group live permanently in nearby settlements whereas others live temporarily in the surrounding as free moving Bedouin tribes.

Products and markets

The timber produced in thinning and in final harvesting operations is sold by weight (t) as it is common practice in the wood market in Ismailia. It is unusual to measure and sell the wood by volume (m^3). Current wood products are timber logs of higher and lower quality with different dimensions, crookedness and branchiness as specified in table 9. At the moment underutilized wood products are poles and stakes which can be derived from tending operations or through short rotation coppice.

Table 17: Quality criteria currently applied for the wood products of the Serapium forest plantation 2012

High quality timber	Stem wood, DBH >11 cm (15 cm); length >1.2m; straight to slightly crooked; no thick branches (small branches are allowed); no damages;
Low quality timber	Stem wood and thick branches; DBH >5 cm; no “high” quality (heavily crooked; thick/ too many small branches; damages)
Poles and stakes	DBH ±5cm; length >2.5m; straight to slightly crooked;

Sales experience only exists for the tree species Pinus halepensis, Eucalyptus camaldulensis, E. citriodora, Casuarina equisetifolia and Cupressus sempervirens. The tree species Khaya senegalensis, Dalbergia sissoo or Terminalia arjuna were never sold on the local market and therefore no information on the demand of these species exist.

At the moment there are four companies at the local wood market that buy wood from the plantation. These companies are located in the Ismailia region or in the near town Fayed. Logs are sold by auction through sealed bid. The buying companies from the region are informed and invited to submit a bid on how much they are willing to pay per ton of the respective wood product. The highest bidder is awarded the contract. Logs from thinning operations are prepared for the auction by the forest workers. A second sales option is to sell the wood of standing trees, which is the preferred method when an entire lot is being harvested. The buyer comes with his own workers and equipment to harvest, load and transport the wood. The plantation workers control the process of cutting and weighing. In this case the sales prices are lower, because the buying company subtracts the harvesting costs from the market value. Buying standing timber, the buyer is faced with a high degree of uncertainty as he usually does not have comprehensive information on the total volume or weight of the lot on offer. Under these circumstances the buyer will usually submit a bid at the lower end to compensate for the risk of uncertainty. Prices range from 80-100E£ for low quality wood from Cupressus until 300/350E£ for higher quality logs of Cupressus, Eucalyptus or Casuarina. Stakes and poles are sold for 1-2E£ per piece.

The expected use of the wood products ranges from fuel wood for the lower qualities and poles for banana plantations until furniture production and veneers for high quality timber logs. No investigation was made on the local wood markets and amongst the local wood processing entrepreneurs about the real use of the wood produced at the plantation. Regarding the overall unsatisfying quality and small dimension of the timber, it is likely that most of the wood is used for lower purposes. The complete overview of the current products, quality criteria and prices can be seen in the annex.

Main threats and conflicts of the Serapium forest plantation

Problems, threats and conflicts which determine the progress and silvicultural success at the plantation were detected at Serapium forest. The following threats, conflicts and problems are a synthesis from the stakeholder analysis, the economic and market analysis, observations during the "Integrated Forest Inventory Training" and literature evaluation. The detection and description of problems is a necessary step to improve the situation at Serapium forest. Therefore the following description must be seen as positive and necessary analysis for the further adjustment of management activities. The detected problems or threats are explained in the center column. The negative effects of the respective problems and threats are listed in the right column "Effects". The stakeholders who are connected to the problem and who should be involved in the problem solving processes are identified and listed in the left column "Stakeholder".

RESPONSIBLE STAKEHOLDER	THREAT / PROBLEM / CONFLICT	EFFECTS
MALR; UAE; plantation administration	-Inter-institutional structures and inappropriate decision making processes (commissions for every problem until ministerial level) are impeding necessary silvicultural or other necessary actions at the plantation. -Limited authorization of the plantation management to carry out necessary silvicultural measures of bigger extend (e.g. harvesting and removal of weak or death Cupressus sempervirens trees for forest health).	-Inflexibility. -Reduced productivity. -Unhealthy forests.
MALR; UAE; MHUUD	-Contamination of water with pathogens and heavy metals (lack of water control and low hygienic standards)	-Health risks for humans (workers and peasants), domestic and wild animals
MALR; UAE; Pump company (Cairo)	-Bad condition of the pumping system. -No adequate schedule for the irrigation system to meet water requirements of the trees. -Missing emergency plan for a breakdown of the pumping system.	-Reduced productivity and vitality. -Total loss of all trees.
MALR; UAE; Local population ("Badus")	-Unauthorized access of people and livestock to the plantation area. -Uncontrolled browsing of the livestock in the forest. -Illegal cutting of trees and theft of equipment.	-Negative health effects for livestock and humans due to heavy metals. -Damage on trees. →Reduced productivity and tree quality. -Loss of equipment.
UAE; Plantation administration; Workers	Insufficient knowledge in silvicultural production cycles and silvicultural techniques (e.g. pruning).	-Reduced tree quality.
UAE, Plantation administration	Missing market analysis and market strategy.	-Unspecified production targets. -inefficient resource allocation

The detected threats and problems affect negatively the silvicultural production in two ways. First, **the overall productivity is reduced**. The bad condition of the pumping system is responsible for an insufficient supply of the parcels with water which reduces increment and vitality of the plants. An extension of the forest area is not possible at the moment. The plantation management cannot react flexible on occurring needs due to slow decision making processes and missing authorization in silvicultural measures so that unproductive tree species and parcels remain in the bad status over a long period. An example is the unhealthy status of many Cupressus stands. Although this situation is reported to the UAE as very urgent and is known within the institutions over a longer period the plantation manager is not allowed to fell and replant the parcels with more appropriate species without an extra permission from the UAE. Even in an emergency the plantation manager cannot react flexible on changing situations. That way the decision making structures lead to underachieve the potential of wood production at the plantation. Second, **the quality of the trees is diminished** through the browsing of livestock from surrounding settlers and inappropriate silvicultural treatment (too early, too late or missing thinning operations, bad pruning techniques).

The **conflict of interest** between the plantation management (production targets) and the local livestock owners (free fodder for the animals) must be highlighted. Negative effects on the production of the plantation and on the health of humans and animals are unpredictable. One attempt to expel the animals from the plantation provoked an assault of armed Bedouins to intimidate the plantation manager and his workers. Since then the animals are accepted in the plantation.

As long as there is no regular proof, it must be assumed that the TWW used for irrigation (nursery and parcels) still contains pathogens. Current practices in handling the TWW expose plantation workers, local population and domestic and wild animals to unforeseeable health risks. Direct hand contact with the TWW, the intake of TWW by hand-mouth contact or the inhalation of droplets in the nursery sprinklers may cause diarrhea or other severe illnesses. Animals may use the discharging nozzles or leaky tubes to allay their thirst.

High amounts of heavy metals recently detected in the leaves of plantation trees (GHORAB et al. 2011) are a dangerous issue. Although EVETT et al. (2011) doubt that the content of heavy metals in soil and plants exceed permissible levels, a comparison with EU legislation shows that concentrations reach critical thresholds for livestock forage (COUNCIL OF THE EUROPEAN UNION 4.5.1999). **5mg/kg is the maximum content of lead (Pb) in the daily ration of animal feeding in the EU. The leaves of plantation trees show a content of lead up to 7.25mg/kg.** If leaves and plant material of the plantation is the only content of the daily ration of the animals over a longer period, than a progressing intoxication of the livestock can be the result. Lead tends to accumulate in organs like liver, spleen and kidneys, but also in blood and muscles. Milking animals pass the lead to the pups. It must be stated, that the browsing of livestock in the plantation can be a severe health risk for the livestock and humans who consume the meat and milk of these animals.

Regarding the health risks due to pathogens and intoxication of humans and livestock, the project risks to lose legitimation for the objective of the safe use of the treated wastewater, unless better hygienic measures are implemented and the local population is informed and kept away from danger!

3.Management Planning 2013-2022

Silvicultural management

The planning of the silvicultural management is based on the analysis of the inventory results and the observations and discussions made during the "Integrated Forest Inventory Training" in September 2012. The general objectives formulated for each species were discussed with and agreed on by the plantation management and aim to contribute to reach the overall plantation objectives (silvicultural, ecologic, social, economic sustainability). The following goals were defined for the silvicultural planning:

- ✓**Core area of management planning is the current forest area:** The current forest area can be maintained when the pumps are repaired. If the pumps are not repaired silvicultural activities must focus on areas near the pumps. If the pumping system is improved, the forest area can be extended.
- ✓**Even distribution of silvicultural activities in space and time:** Silvicultural activities (planting, thinning, harvesting) shall utilize the available working capacity at the plantation. Periods of too many activities or periods with no activities shall be avoided. The regular distribution of planting, thinning and harvesting operations guarantees continuous wood production and supply of the markets.
- ✓**Increase in wood production:** Consistent substitution of failed species with successful species, which showed good growth in the past, will lead to higher increments and therefore to a higher use of TWW as well as to higher market shares of wood products.
- ✓**Improvement of wood quality:** Wood quality will improve through the implementation of silvicultural measures according to best management practices. The production of big diameter valuable wood for higher end uses shall not be declared production target.
- ✓**Species diversity:** Silvicultural planning shall foster successful species but also maintain certain species diversity. This will help to reduce risks of total losses of one species (e.g. due to diseases), to adapt to different site conditions and to diversify the wood products for market sales. The target share of each species adjusted.
- ✓**Diversity in structures:** The overall structure of the plantation shall be maintained and huge mono-cultural blocks of only one species shall be avoided. To optimize wood production due to water availability parcels can be planted with two species where possible. In the central part (where water supply is high, close to the main irrigation line) high increment species (e.g. Eucalyptus) are preferred, at the margins of the irrigated area drought resistant species (e.g. Casuarina).
- ✓**Rotation length:** Rotation length is directed by the growth performance, production targets and the specific site conditions and risks (increasing risk of losses due to irrigation problems, higher risk of wind throws with increasing height).

Production targets

The production of high quality wood for high-end uses like veneers and furniture would require predictable and favorable environmental conditions for regular growth and a high input of resources and silvicultural knowledge (species and seedling selection, tending, pruning, thinning operations, etc.). The high quality logs must be sold at prices that justify the high input of resources. Another production strategy is to generate income by following the principles of an economy of scale with focus on high production rates and lower inputs and with the purpose to supply markets with medium quality wood for normal end uses. For this strategy tending and thinning operations should be reduced to a minimum, pruning is not foreseen. Both strategies require optimization strategies to allocate resources according to available forest areas and production targets. For an optimal allocation of resources a cost benefit analysis (together with a market analysis) must be carried out by the UAE to determine the best production system (quality and/or mass production) to achieve the multiple objectives of the Serapium forest.

The current inferior plantation quality, the insecure climatic conditions, the problems with the irrigation system and the unknown market conditions favor to increase productivity and to focus on the production of medium quality wood with maximum 20cm - 25cm DBH. Tree species with high increment shall be favored. Wood quality will be improved by implementing appropriate silvicultural treatments as they were presented during the “Integrated Forest Inventory Training” and as described in the chapter “Silvicultural Interventions to improve wood quality”. Pruning can be carried out (but it is not recommended) if it is done correctly.

Silvicultural measures per species and future species composition

The Serapium forest inventory has revealed the most critical and most successful species (adaptation to local conditions and contribution to plantation objectives). Silvicultural status, targets and recommended treatments for each species are formulated and summarized in table 18. To increase productivity it is necessary to focus on good performing species, whereas unsuccessful species shall not be considered for the future species composition, except as demonstration models in small areas. The future desirable species composition is shown in the right column of table 18. The future species composition will be reached by implementing the harvesting plan with corresponding reforestations and by following silvicultural recommendations of this management plan.

Table 18: Silvicultural targets and recommended future share of tree species

Productive and protective forest area:		
	Casuarina equisetifolia	32%
	Successful species, drought tolerant. Fostering of the species and extension of the area. Planting in dryer areas and in parcel margins.	
2002	Thinning (silviculture according to general production schema).	
2006	Pruning of max 80 trees/ ha which show good vitality, straight stem, no damages and DBH ±10cm.	
	Cupressus sempervirens	1%
	Replacement with more successful species. Preservation of one parcel for demonstration purposes and research.	
2002	Immediate removal of dead and unhealthy trees.	
	Dalbergia sissoo	1%
	Maintenance of existing area, no further extension of Dalbergia.	
2007	Thinning for forest health (removal of suppressed/ overtopped/ unhealthy trees).	
	Eucalyptus citriodora	35%
	Most promising species. Fostering and extension of the existing area. Silviculture according to general production schema.	
	Eucalyptus camaldulensis	13%
	Maintenance of existing area, no further extension due to problems with browsing and diseases.	
	Khaya grandifoliola	0%
	Replacement with more successful species (e.g. Eucalyptus ssp., Casuarina ssp.)	
	Khaya senegalensis	12%
	Maintenance of current stands which show reasonable condition. Planting of K. only in well irrigated areas (low elevations or near pumps), silviculture according to general production schema. Lower elevations: thinning operations. Higher elevations or in dry areas: replacement with more successful species.	
2002	Thinning for PCT (selection of 80-100PCT/ ha and removal of 2 competitors). Thinning for forest health (removal of suppressed/ overtopped/ unhealthy trees).	
2004	Stands in reasonable condition: Thinning for PCT (selection of 80-100PCT/ ha and removal of 2 competitors). In dry parts: replacement with more successful species.	
2007	Stands in reasonable condition: Thinning for PCT (selection of 80-100PCT/ ha and removal of 2 competitors). In dry parts: replacement with more successful species.	
	Pinus halepensis	1%
	Unsuccessful species. Replacement with more successful species. Maintenance of one parcel for demonstration purposes and research.	
	Terminalia arjuna	2%
	Maintenance of current area in the next years. Bad quality but good health status. No specific treatments.	
		97%
Demonstration forest		**1-2%**
Experimental area		**1-2%**
Forest area (128/5ha)		**100%**

Rotation length

The recommended rotation length of each species is a compromise between production targets and biophysical constraints. A target DBH of 20cm (25cm) is currently totally sufficient to satisfy local market demands for wood of medium quality. Within the range of years to reach the threshold of 20cm DBH the risk of tree loss increases (e.g. as observed in Eucalyptus camaldulensis stand from 2004). Main risks are more frequent wind throws and severe health problems of trees related to insecure and irregular irrigation.

The potential rotation length of each species is calculated by dividing target DBH by the mean annual diameter increment (table 19). In average a rotation length of 13years is needed to reach 20cm DBH. Unsuccessful species like Cupressus or Pinus were not considered for determining the mean rotation length because these species will be replaced in future. Under the current situation of the irregular irrigation at the parcels (less water supply at the parcel margins), it is likely that only trees in the best irrigated parts of the parcels will reach the target DBH. Commercial DBH and rotation length can be adjusted where necessary. For further calculations a mean rotation length of 13years is assumed.

Table 19: Rotation length per species

Species	Planting year	Age (years)	Mean Dbh (cm)	Δ Dbh (cm)/year	Estimated rotation length (years) to reach commercial Dbh[cm]		
					15	**20**	**25**
Casuarina equisetifolia	01/3/2002	10.7	13.3	1.2	-	16	20
	01/3/2006	6.7	8.7	1.3	-	15	19
						16	**20**
Cupressus sempervirens	01/3/2002	10.7	13.5	1.3	-	16	20
Dalbergia sisso	01/3/2007	5.7	10.0	1.8	-	**11**	**14**
Eucalyptus camaldulensis	01/3/2004	8.7	15.9	1.8	-	11	14
	01/3/2006	6.7	10.2	1.5	-	13	16
	01/3/2008	4.7	8.0	1.7	-	12	15
	01/3/2011	1.7	3.8	2.3	-	9	11
						11	**14**
Eucalyptus citriodora	01/3/2007	5.7	10.3	1.8	-	11	14
	01/3/2008	4.7	8.8	1.9	-	11	13
	01/3/2010	2.7	5.0	1.9	-	11	13
						11	**13**
Khaya senegalensis	01/3/2002	10.7	12.9	1.2	-	16	21
	01/3/2004	8.7	11.3	1.3	-	15	19
	01/3/2007	5.7	10.5	1.9	-	11	13
						14	**18**
Pinus halepensis	01/3/2002	10.7	15.0	1.4	-	14	18
Terminalia arjuna	01/3/2005	7.7	9.8	1.3	12	-	-
	01/3/2007	5.7	8.2	1.4	10	-	-
					11		
Average (without Cupressus, Pinus and Terminalia)					**-**	**13**	**16**

Annual yield (area & volume)

The harvesting schedule in the Serapium forest should observe the principle of economic and ecological sustainability which postulates that no more wood shall be harvested and removed from the forest in a certain period than is growing within this time. Harvesting operations shall be distributed evenly over the years to keep operational activities, work volume and employment at the same level. To estimate sustainable harvest, the classic method of area regulation is used to determine the annual harvestable area (AHA) and to estimate the annual harvestable volume (AHV). A stand, which can be harvested after ±13 years at the end of rotation (u) shall be replanted and harvested again after the end of the next rotation period (u). While one stand is replanted and growing to maturity another stand will reach the end of the rotation period and will be harvestable. Following this schedule a sustainable harvesting cycle can develop so that each year a certain area can be harvested in a rotating system. The AHA of final harvest (f) can therefore be determined by dividing the total forest area that is available for harvesting (F) by a defined rotation length (u) (KNOKE *et al.* 2012: 23ff):

$$AHA = \frac{F}{u}$$

$$AHA_{Serapium} = \frac{118ha}{13a} = 9ha/a$$

a=annum (year)

Under the conditions at Serapium the outcome of this calculation is an AHA of 9ha. 118ha is the current net forest area covered by tree species plus the area of Sisal that shall be replanted in the year 2013. The average rotation length of 13 years is calculated in the chapter above. The method assumes an even age class distribution at Serapium forest, which is not the case now. However, it may be possible to develop an even age class distribution within the first rotation cycle of 13 years.

Additionally this method copes well with the needs at Serapium forest to plan and schedule silvicultural activities. Cutting each year a forest area of the same size (in case of Serapium this will be 9 ha each year) is a comprehensible and widely recognized silvicultural management approach to be implemented by the plantation management and the workers. Based on this AHA the **HARVESTING PLAN 2013 2022** has been developed (chapter "**HARVESTING PLAN 2013 2022**"). It is a periodic harvesting plan that identifies for each year those parcels which reach the end of rotation and which sum up to 9ha each year.

With the help of the annual harvestable area (AHA; ha) the annual harvestable volume (HV; m^3/ha) can be deduced:

$$HV = AHA * HV_u$$

At Serapium the final stands shall be harvested when they reach the end of rotation 'u' (see **HARVESTING PLAN 2013 2022**). 'HV_u' can therefore be estimated by multiplying the rotation length (u) with the MAI of the respective species:

$$HV_u\left(\frac{m3}{ha}\right) = MAI\left(\frac{\frac{m3}{ha}}{a}\right) * u(a)$$

The MAI used for this calculation reflects the current situation at the plantation (irregular growth within parcels due to irregular irrigation, no thinnings until final harvest) and does not give growth potentials of the best growing stands and trees. In future years, when silvicultural interventions (see chapter "Silvicultural Interventions to improve stand and wood quality - **WOOD PRODUCTION SCHEME IN 5 STEPS**") will be implemented and irrigation will be improved, the MAI is expected to increase considerably. Then, the HV must be recalculated more precisely, e.g. as already calculated for growth potentials by EL-KATEB (2012).

Due to the fact that Serapium forest is no mono culture plantation, the HV will be composed of different species with its respective ‘AHA $_n$’ and respective ‘PHV $_n$’. ‘AHA $_n$‘ represents in this case the size of a parcel. ‘HV $_{year\ x}$’ must be calculated as sum of the HV of each species in the respective year for each year (HV $_{1-n}$):

$$HV_{year\ x} = AHA_1 * HV_{u,1} + AHA_2 * HV_{u,2} + \cdots + AHA_n * HV_{u,n}$$

$$HV_{year\ x} = HV_1 + HV_2 + \cdots + HV_n$$

To calculate the commercial harvestable volume (HV $_{com}$) (wood volume that can be sold), the HV of each species (HV $_{1-n}$) must be reduced by an estimated 20% for harvesting losses (e.g. damaged trees).

$$HV_{com} = HV - 20\%$$

$$HV_{com} = (HV_1 - 20\%) + (HV_2 - 20\%) + \cdots + (HV_n - 20\%)$$

Table 12 gives an overview which yields can be expected per species at the end of rotation. The MAI in table 20 is the average of the MAI of each species from table 8 and is therefore lower than the MAI of the best performing stands from table 8. Lowest yields are expected with Casuarina equisetifolia whereas best yields are predicted for Khaya senegalensis and Pinus halepensis. Eucalyptus camaldulensis and Eucalyptus citriodora are good performing. The harvestable volume of Eucalyptus citriodora is expected to be even higher. Expected harvestable volumes in table 20 shall not mislead silvicultural decisions. Although increments and HV seem to be very high, Pinus is currently performing very poor and stems of Khaya show poorer quality than desired. Expected HV is only one aspect in a holistic view for decision making in forest management.

Table 20: Estimated yields per species at the end of rotation (1ha)

Species	Mean annual volume increment, 'MAI' (m^3/ha/year)	Rotation length 'u' (years)	HV (AHA=1ha) (m^3/ha)	HV_{com} (HV -20%) (m^3/ha)
Casuarina equisetifolia	4.5	13	58.5	46.8
Cupressus sempervirens	6.3	13	81.3	65.0
Dalbergia sisso	5.6	13	72.7	58.1
Eucalyptus camaldulensis	8.2	13	107.0	85.6
Eucalyptus citriodora	7.0	13	90.6	72.5
Khaya senegalensis	9.3	13	120.3	96.3
Pinus halepensis	9.3	13	120.9	96.7
Terminalia arjuna	5.9	13	76.4	61.1

The data in table 12 form the basis for estimating the final HV for each year of the **HARVESTING PLAN 2013 2022.** For example Eucalyptus citriodora of parcel #1 (0.7 ha) is scheduled to be harvested after 10years after planting in the year 2020. ‘HV_{com}’ yield of this species is estimated to be 39.2m^3. The respective calculation is:

$$HV_{parcel\,1,2020} = AHA_{parcel1} * HV_{u,parcel1}$$

$$HV_{parcel\,1,2020} = AHA_{parcel1} * MAI_{parcel1}\left(\frac{\frac{m3}{ha}}{a}\right) * u(a)$$

$$HV_{parcel\,1,2020} = 0.7ha * \left(7.0\frac{m^3}{ha}/a * 10a\right) = 49.0m^3$$

$$HV_{com\,parcel1,2020} = 39.2m^3$$

Silvicultural treatments can be shifted from one year to another due to silvicultural or managerial needs. In case the wood is sold by fresh weight, potential revenues from wood sales can be estimated as follows:

$$Revenue\,(\text{E£}) = HV_{com}(m^3) * wood\,density\left(\frac{kg}{m^3}\right) * wood\,price(\frac{\text{E£}}{kg})$$

In future it will be an important task for the plantation management to record and document timber sales by species, volume, weight, quality, and if it originates from thinning or final felling, in order to establish a databank which will facilitate economic planning. Over the years more precise predictions on yields will be possible.

General zoning of the plantation area

The identification of forest areas with specific functions facilitates future silvicultural planning. Forest areas for protective forest, productive forest, demonstration forest and experimental areas were identified. The respective areas are shown in map 3 ("Serapium Forest, Ismailia – Forest Functions 2013-2022"). Table 21 gives the share of each area at the plantation area.

Table 21: Forest functions at Serapium forest plantation

	ha	%
Protective forest	29.8	19%
Productive forest	118.9	76%
Demonstration forest	1.5	1%
Experimental area	6.6	4%
Plantation area	**156.8**	**100%**

Protective forest

The zones of protective forests at Serapium have mainly one purpose: to protect the trees and stands in the plantation from strong winds coming from the plain desert area in the surrounding. Positive effects of a reduced wind speed are a reduction of wind throws risks (wind throws were observed in the north western part of the plantation), a reduction of the evapotranspiration and higher soil moisture. Therefore a ring of permanent forest with an overall width of ±15m (up to 5 tree rows if necessary) shall be developed around the whole plantation area. Main focus shall be laid on the north western plantation border. In the outlines of this permanent protective forest belt a shelterbelt of shrubs shall be established. Outside the ring road there is no irrigation system. Therefore suitable drought resistant species like Acacia saligna and Tamarix should be chosen. Planting drought resistant thorny shrub species would add the function of a natural barrier against browsing animals to the surrounding shrub belt. The belt of protective forest should be composed of shrubs and Casuarina trees, which are commonly used for shelterbelts. Up to five tree rows with the regular planting spacing should be kept alive by steady water supply.

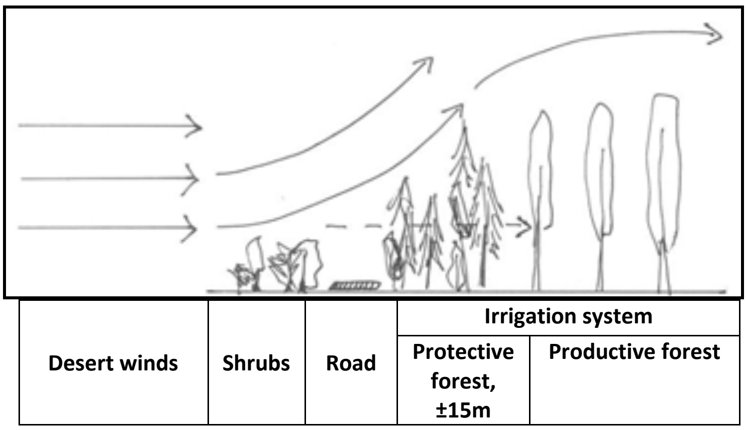


Figure 9: Recommended structure for forest borders (Graphic: A. Kress, FAO)

A well established forest border should show an increasing height of the plants from the outside border into the plantation as shown in figure 9. The winds can slide over the forest border and trees. It is recommended that the forest border is not too close, so that entering wind is slowed down. It is important to maintain a permanent forest cover which demands following silvicultural management:

- No clear cutting but (Clear cutting would open the shelterbelt and expose stands to direct wind).
- Continuous removal and replanting of single trees
- Operations must aim to maintain the wedge-shaped structure of the forest border.

Productive forest

The main part of the forest area is dedicated to the production of wood. The focus of the silvicultural planning for productive purposes shall lie on species with high increment and which are easy to manage to reach the objectives of an increased wood production and increased quality. The most promising species for wood production are currently Eucalyptus and Casuarina in dryer areas. The area of these species shall be extended. Khaya senegalensis shows good increment (with sufficient water supply) but low quality and no market experience exists for this species. The current practice to surround each parcel with a shrubby shelterbelt can be continued. These shrubs serve as additional wind brakes within the plantation and grow in areas of the parcels where water supply of the current irrigation system is too low for tree growth.

Demonstration forest

One parcel of Pinus halepensis and one of Cupressus sempervirens which showed best health status (average vitality = "healthy") were selected to serve as demonstration forest. The two mentioned species can be regarded as unsuccessful and shall be replaced in the next years but the selected parcels shall be kept alive and remain as demonstration objects to show unsuccessful species and to serve for research.

Experimental area

The experimental area is dedicated to growth experiments for new species or provenience trials of existing species. Purpose is either the identification of higher growth potentials of woody species or the use of non-timber products. Currently *Jatropha curcas* (plant oil from the fruits) and *Jojoba* (*Simmondsia chinensis*, medicinal oil) are planted on experimental parcels in the south western part of the plantation. The currently uncultivated parcels of the identified experimental area can be transformed into productive forest area if it is not used for species trials.

Silvicultural Interventions to improve stand and wood quality

Wood production scheme in 5 steps

To improve wood production at Serapium forest it is recommended to implement and conduct regular silvicultural procedures from stand establishment until final harvest. The below described silvicultural measures can be implemented in existing stands or in newly established parcels. A description of steps 1 - 5 is given below.

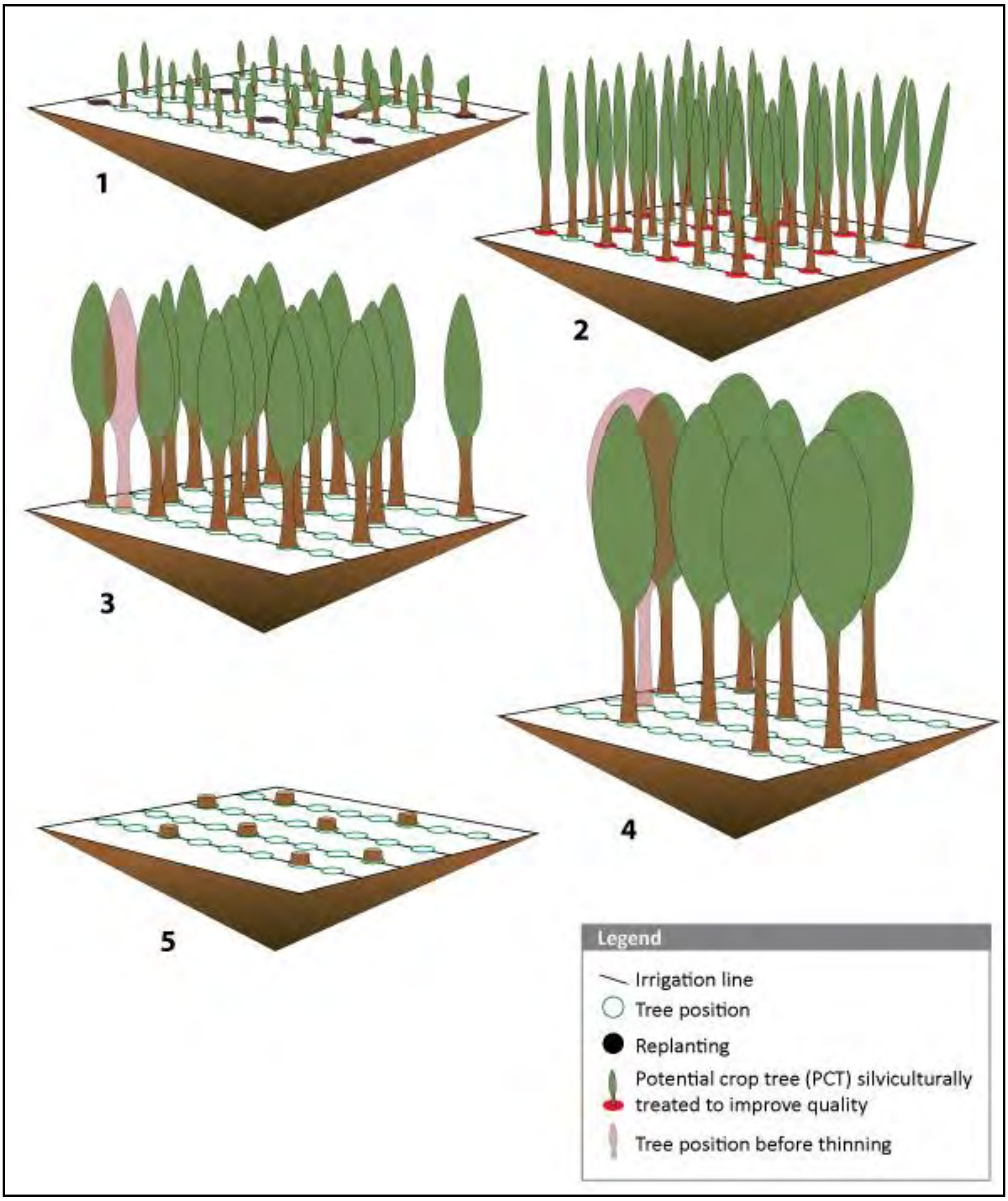


Figure 10: General wood production scheme for forest plantations (Graphic: R. Cenciarelli, FAO)

Planting and replanting (1)

The establishment of timber stands with seedlings requires homogenous and high quality planting stock (WEINLAND et al. 1995: 15). A strict control and selection of quality parameters must be carried out before planting. Quality parameters are well developed roots, good root-shoot-ratio, good vitality, a straight main shoot, no bifurcation, no damages or pests and diseases (RÖHRIG et al. 2006: 158ff). The plant handling must be done with care to avoid damages before and while planting. Seedlings raised in polybags should not be older than 2 - 3 months when planted to avoid root deformations in the bag (spiral growth). The roots must be kept fresh before planting and planting techniques must guarantee a proper positioning of the seedling in the sandy soil without deforming the roots. Continuous water supply must be guaranteed and the quantity of water provided must be increased with the growth of the plants. Planting distance is determined by the irrigation system to 3m x 3m.

In the years after planting the survival and quality of all seedlings must be regularly controlled. Dead or damaged seedlings must be replaced before the seedlings reach a height of ±1.5m. The seedlings must be protected from browsing. Weed control is not necessary as weed growth is negligible.

A growth gradient is observed in each parcel with best growth in the central part of a parcel near the main irrigation tube and less growth towards the edges of a parcel. This is related to the declining water supply with increasing distance from the main water pipe of each parcel. One option to deal with the problem of different site conditions is to adjust the choice of species to correspond to the distribution pattern of the water supply as shown in figure 11: A fast growing species (e.g. Eucalyptus citriodora) in the central part of the parcel where water supply is sufficient, and a more drought resistant species (e.g. Casuarina) at the edges of a parcel where water supply is scarce. The result would be mixed stands or respectively narrower strips of two different tree species at each parcel. The use of water resources would be optimized. On the other hand silvicultural management would become more complex.

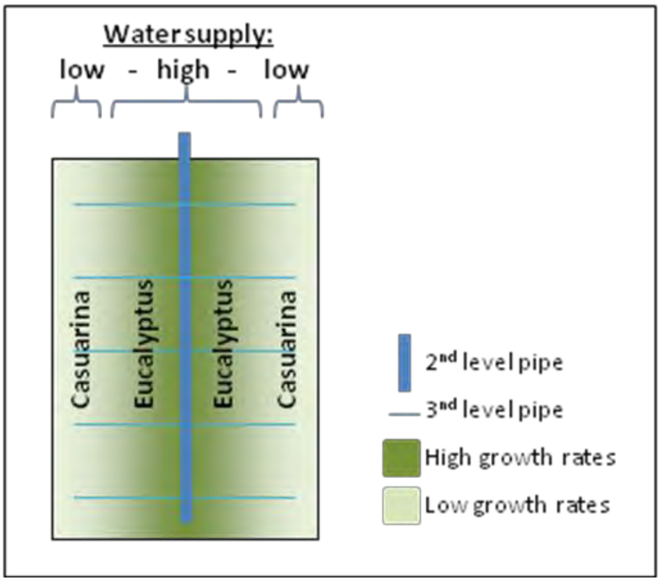


Figure 11: Recommended species distribution in one parcel

Tending and pruning operations (2)

When the trees reach a total height of 4-5m or a DBH of ±5cm but before crown closure (1st - 2nd year after planting), the potential crop trees (PCT) at every second position must be silviculturally treated. Possible interventions are: removal of competing trees in the same position, pruning of the first 2-3m of the stem, removal of forks. Untreated trees will be removed in step 3.

Trees are treated when they are young but the timing depends by the growth rapidity. Therefore it should be done at the end of the first year or during the second year after planting or when the plants reach a DBH of ±5cm. The tending intervention corrects malformations to ensure the development of straight trees and is more effective when the branches are small. It is important not to remove too many branches to avoid stress.

Pruning is the controlled removal of branches from a tree to produce high quality round wood that is free of branches. Pruning is a costly operation, and the investment made to execute it should be in relation to an additional benefit in future years. The stubs left from pruning must be short so that the trees can close the wound in a short time period. Damages to the cambium of the tree must be avoided. The trees to be pruned should be PCTs of a small diameter, so that future diameter growth produces as much branch free wood as possible. If carried out, pruning should focus only on PCTs of the final stand to reduce costs.

Pruning is not recommended when	**Pruning is recommended when**
–a species cannot be used as valuable wood (e.g. fuel wood). –a tree has a bad quality and it is not possible to improve it. –it is too late to improve the quality of a tree (e.g. DBH larger than 10cm). –a species is self pruning (e.g. Eucalyptus citriodora).	–the wood market demands for branchless stem wood for high-end purposes (good quality sawn wood or veneer) (Weinland et al. 1995: 17). –trees of a species show enough growth and increment to reach the required quality parameters (minimum diameter of branchfree wood) within the rotation length

First thinning and second pruning (3)

Thinning is the removal of trees from a stand within the course of a rotation with the following objectives (WEINLAND et al. 1995: 17):

- –stand quality is improved by removing poorly formed, damaged and diseased trees,
- –future increment is concentrated on the best formed trees,
- –more growing space is provided for final crop trees to enhance crown size and subsequently diameter increment,
- –stability of the stand is enhanced by giving more growing space to the roots of the potential final crop trees

The decisive parameters for thinning operations are the height of the commercial bole, general tree height and the canopy closure. Competition in the canopy forces trees to grow towards the light, the crown tips will move upwards. When a commercial bole height of approximately 4-5m is reached the silvicultural goal should be to increase stem diameters. PCTs should be liberated from competition.

High canopy density is a sign for competition and a first thinning should be conducted (removal of every 2nd tree that was not treated in the tending operation). If necessary the development of the commercial bole can be improved by further pruning up to a height of 4-5m but before stems reached a DBH of ±10cm.

Second thinning (4)

Silvicultural goal is the diameter increment of the final crop trees. Competition among trees must be regulated and the final crop trees must be provided with the required growing space in the crown and root layer. The intensity of the second thinning depends on silvicultural experience and production targets. A schematic approach is recommended if the production target is general utility timber. Possible schemes are to cut every second tree or to cut the trees along every second irrigation line.

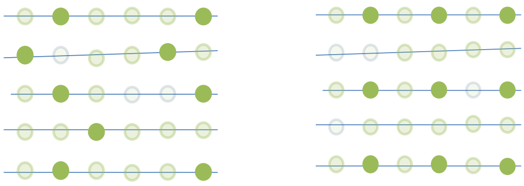


Figure 12: Options for schematic thinning operations

Another option is to select 80-100PCT/ha with high quality and liberate them from 2 competitors. If the second thinning is necessary depends on the competition among trees.

Harvesting (5)

When the production goal is achieved (e.g. commercial diameter at the end of rotation) good market conditions should be taken advantage of (WEINLAND et al. 1995: 17) and the parcel should be cleared and replanted. The length of the harvested logs must be defined before the felling in order to obtain the intended round logs from the harvesting operation. The management cycle starts again with replanting (1).

Plant protection and health (pests, diseases, browsing, fire)

During the entire production period the health status must be controlled and potential risks of losing single trees or entire stands must be reduced to a minimum. Currently, pests and diseases (unknown gall wasps and leaf diseases) have damaged young plants of Eucalyptus camaldulensis. Their further development must be monitored, but at the moment it is not recommended to replant this species.

Forest plants must be protected from browsing by domestic camels and donkeys. In this respect careful negotiation with the animal owners are recommended. One option is to concentrate browsing on shrubs and plants that are not used for wood production. But if the health risk for animals due to heavy metals is too high, access to the plantation area must be rejected. Also if the animal owners are not willing to cooperate then the entire plantation area should be fenced or single plant protection with tubes or wire mesh should be considered. Both options are expensive. Temporary fences could also be an option wouldn't there be the problem of theft.

Fire is always a risk to forest stands, especially with the extremely dry climatic conditions of Egypt. Understorey and thick layers of dry leaves are potential fuel material that can burn quickly. Although one small forest fire already occurred at the plantation (it was reported that it was lighted by an angry animal owner) fire is not considered as risk. However as preventive measures camp fires of the guards and smoking in the plantation should be forbidden and the thick layers of dry leaves on the floor must be removed. The structure of the plantation is advantageous for fire mitigation. The secondary sand roads between the parcels function as vegetation-free strips that can halt a forest fire.

HARVESTING PLAN 2013-2022

Harvesting shall take place at the end of rotation (13years) when the trees have reached the commercial target of 20cm (25cm) DBH. The **HARVESTING PLAN 2013-2022** sets up a precise time schedule for the final harvest of stands which will reach the end of rotation within the next ten years. At the same time harvesting activities are scheduled to achieve a sustainable annual harvested area of 9ha (see chapters "Rotation length" and "Annual yield").

In the first planning period (2013-2015) it is recommended to harvest more than the calculated regular annual yield, in order to be able to quickly remove unsatisfactory species and replace them by more promising ones. Therefore first harvest priority is given to parcels where health status and growth patterns make immediate interventions necessary (e.g. the replacement of Cupressus sempervirens and the replanting of the Sisal area). Towards the end of the total planning period the area of the annual yield is lower than 9 ha. This is caused by the age class distribution of the stands. A majority of the parcels was planted in recent years or will have been afforested in the first period by replacing *Cupressus* and Sisal. These stands will reach the end of rotation after the year 2022.

Environmental impacts (diseases, wind throws, etc.), technical problems (irrigation) or other considerations of the plantation management may prompt decisions to deviate from the intended schedule and to shift the treatment or the harvest of a parcel to another year. Nevertheless it is recommended that the plantation management implements the silvicultural interventions of the **HARVESTING PLAN 2013-2022** as best as possible.

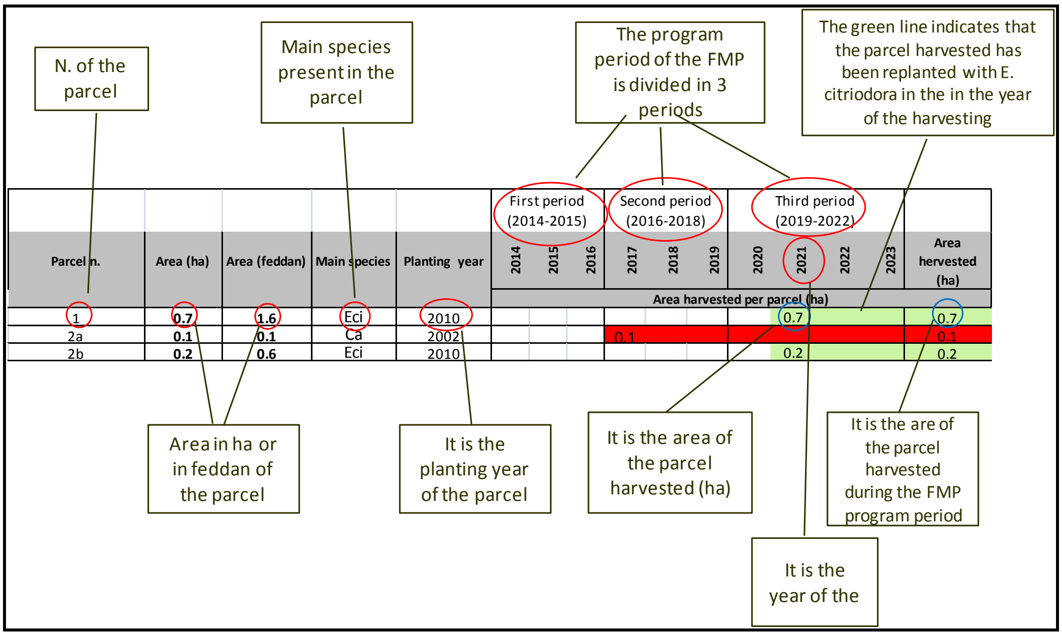


Figure 13: Explanation of the HARVESTING PLAN 2013-2022 (1)

The left columns (figure 13) of the **HARVESTING PLAN 2013-2022** give parcel number, parcel area in hectare and feddan, main species (figure 12) and planting year. In the columns that follow (years 2013-2022) is indicated when the parcel shall be harvested. When the entire parcel shall be cut, the hectare value is repeated. If only parts of a parcel shall be harvested or a harvest shall be carried out in different years, it can be indicated by partial hectare values (in the case of Serapium the entire parcels shall be cut). To control the harvested area the hectare values are summarized in the right column after the scheduled years. Remarks indicate if the parcel requires special treatment (figure 14).

Silvicultural treatment		
Con	=	**Con**servation of the parcel as demonstration forest
Fh	=	**F**orest **h**ealth treatments (removal of dead/ unhealthy/ overtopped trees)
Fob	=	Establishment of a **fo**rest **b**order

Figure 14: Required special treatments in certain parcels

Right after the harvest an immediate replanting of the parcel is recommended. Colors (figure 15) indicate which species shall be planted to achieve the future recommended species composition (see chapter "Silvicultural measures per species and future species composition").

Species Description				
Casuarina equisetifolia	= Ca	Bambus	=	Ba
Cupressus sempervirens	= Cu	Jatropha curcas	=	Ja
Dalbergia sissoo	= Da	Jojoba (Simmondsia chinensis)	=	Jo
Eucalyptus camaldulensis	= Eca	Uncultivated	=	Unc
Eucalyptus citriodora	= Eci			
Harpullia	= Hp			
Khaya grandifoliola	= Kg			
Khaya senegalensis	= Ks			
Pinus halepensis	= Pi			
Terminalia arjuna	= Te			
Agave sisalana	= Si			

Figure 15: Colors indicate the species which shall be planted after harvest

The end of the **HARVESTING PLAN 2013-2022** (figure 16) gives the total forest area in hectare and feddan. As explained above an area of 9ha shall be harvested each year which is the "Regular harvested area (ha)". The area of the parcels which are scheduled to be harvested each year sums up in the row "Real harvested area (ha)" and may differ from the theoretical 9ha. In some years the difference is negative, which means that less than 9ha are harvested in the respective year. In such a year nevertheless more than 9 ha can be under silvicultural treatment. For example uncultivated parcels can be scheduled in such a year to be replanted but the area of these parcels is not considered as harvested area.

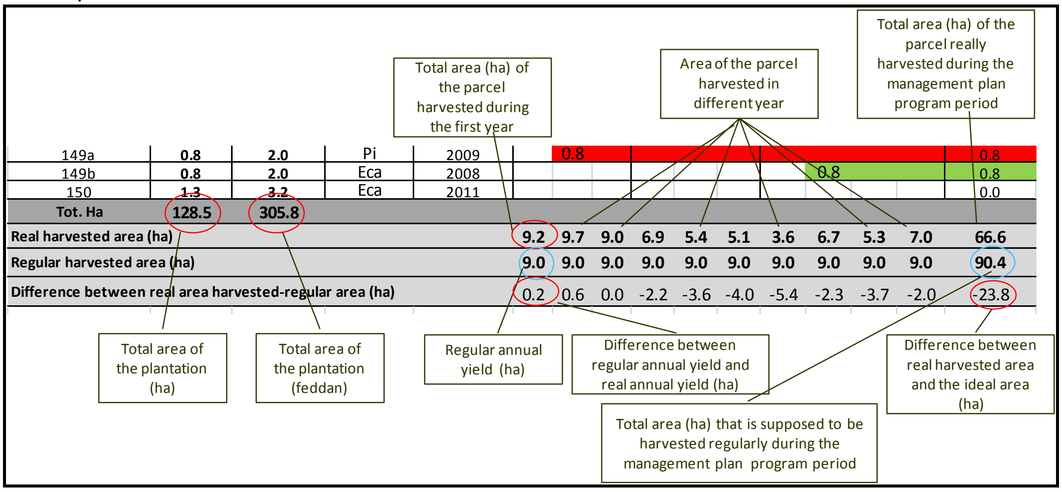


Figure 16: Explanation HARVESTING PLAN 2013-2022 (2)

Table 22: Harvesting plan 2013-2022, Serapium Forest, Ismailia

Parcel n.	Area (ha)	Area (feddan)	Main species	Planting year	First period			Second period			Third period				Area harvested (ha)	Remarks
					2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
					Area harvested per parcel (ha)											
1	**0.7**	**1.6**	Eci	2010								0.7			0.7	Fob
2a	**0.1**	**0.1**	Ca	2002				0.1							0.1	Fob
2b	**0.2**	**0.6**	Eci	2010								0.2			0.2	Fob
3a	**0.2**	**0.4**	Ca	2002				0.2							0.2	Fob
3b	**0.5**	**1.3**	Eci	2010								0.5			0.5	Fob
4	**0.1**	**0.1**	Eci	2010											0.0	Fob
5	**0.2**	**0.6**	Eci	2012											0.0	Fob
6	**1.0**	**2.3**	Eci	2012											0.0	
7	**0.9**	**2.2**	Pi	2008		0.9									0.9	Fob
8	**0.1**	**0.3**	Unc	0											0.0	Fob
9	**0.1**	**0.2**	Eci	2010											0.0	Fob
10	**1.0**	**2.4**	Cu	2002				1.0							1.0	Fh
11a	**1.3**	**3.2**	Eca	2012											0.0	
11b	**0.1**	**0.2**	Eca	2010											0.0	
12	**0.3**	**0.8**	Eca	2010										0.3	0.3	Fob
13	**1.5**	**3.7**	Cu	2002					1.5						1.5	Fh,Fob
14a	**1.5**	**3.5**	Cu	2002		1.5									1.5	Fh
14b	**0.3**	**0.6**	Cu	2002		0.3									0.3	Fh, Fob
15	**1.5**	**3.5**	Cu	2002		1.5									1.5	Fh, Fob
16a	**1.3**	**3.1**	Cu	2002				1.3							1.3	Fh
16b	**0.3**	**0.6**	Eca	2009										0.3	0.3	Fob
17a	**0.4**	**1.0**	Cu	2002		0.4									0.4	Fh, Fob
17b	**0.5**	**1.1**	Eca	2012											0.0	
18a	**0.1**	**0.2**	Cu	2002			0.1								0.1	Fh
18b	**0.6**	**1.3**	Eca	2011											0.0	
18c	**0.5**	**1.1**	Eca	2012											0.0	
19a	**0.2**	**0.6**	Cu	2002			0.2								0.2	Fh
19b	**1.0**	**2.5**	Eca	2012											0.0	
20a	**0.7**	**1.7**	Cu	2002			0.7								0.7	Fh
20b	**0.6**	**1.4**	Eca	2012											0.0	
20c	**0.2**	**0.6**	Eca	2011											0.0	
21a	**0.7**	**1.6**	Cu	2002			0.7								0.7	Fh
21b	**0.8**	**1.8**	Eca	2012											0.0	
22a	**0.2**	**0.5**	Ks	2007					0.2						0.2	Fh
22b	**0.8**	**2.0**	Hp	2007											0.0	
22c	**0.4**	**0.9**	Te	2007											0.0	Fh

Parcel n.	Area (ha)	Area (feddan)	Main species	Planting year	First period			Second period			Third period				Area harvested (ha)	Remarks
					2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
					Area harvested per parcel (ha)											
22d	**0.4**	**0.9**	Ks	2007					0.4						0.4	Fh
23	**1.8**	**4.4**	Ks	2007					1.8						1.8	Fh, Fob
24a	**1.1**	**2.5**	Ks	2007					1.1						1.1	Fh
24b	**0.6**	**1.5**	Eca	2010										0.6	0.6	Fob
25a	**0.5**	**1.2**	Ca	2002				0.5							0.5	Fob
25b	**0.4**	**1.0**	Ks	2007					0.4						0.4	Fh, Fob
25c	**0.2**	**0.5**	Eci	2012										0.2	0.2	Fob
26	**0.2**	**0.4**	Ca	2002				0.2							0.2	Fob
27	**1.4**	**3.3**	Ks	2002										1.4	1.4	Fh, Fob
28	**1.4**	**3.3**	Ks	2002						1.4					1.4	Fh
29	**1.5**	**3.5**	Ks	2002									1.5		1.5	Fh
30	**1.3**	**3.0**	Ks	2002							1.3				1.3	Fh
31	**1.3**	**3.1**	Ks	2004											0.0	Fh
32	**1.4**	**3.4**	Ks	2004											0.0	Fh
33	**1.3**	**3.2**	Ks	2004											0.0	Fh
34	**1.5**	**3.5**	Ks	2004											0.0	Fh
35a	**0.7**	**1.6**	Ks	2004											0.0	Fh
35b	**0.7**	**1.7**	Eci	2012										0.7	0.7	
36	**1.3**	**3.0**	Eci	2010										1.3	1.3	Fob
37a	**0.6**	**1.4**	Eca	2004						0.7					0.7	Fob
37b	**0.9**	**2.1**	Ca	2002				0.9							0.9	Fob
38	**0.4**	**1.0**	Cu	2002			0.4								0.4	Fh, Fob
39	**0.5**	**1.1**	Cu	2002			0.5								0.5	Fh, Fob
40	**0.4**	**1.1**	Cu	2002			0.4								0.4	Fh, Fob
41	**0.4**	**1.0**	Cu	2002			0.4								0.4	Fh, Fob
42	**0.4**	**1.0**	Cu	2002				0.4							0.4	Fh, Fob
43	**0.4**	**1.0**	Cu	2002				0.4							0.4	Fh, Fob
44	**0.4**	**0.9**	Cu	2002				0.4							0.4	Fh, Fob
45	**0.5**	**1.2**	Da	2007											0.0	Fh, Fob
46	**0.4**	**0.9**	Ks	2007											0.0	Fh
47	**0.3**	**0.8**	Eci	2010									0.3		0.3	
48a	**0.2**	**0.5**	Eci	2010									0.2		0.2	
48b	**0.2**	**0.5**	Ks	2007											0.0	Fh
49	**0.4**	**1.0**	Ks	2007											0.0	Fh
50	**0.4**	**1.0**	Ks	2007											0.0	Fh
51	**0.4**	**1.0**	Ks	2007											0.0	Fh
52a	**0.2**	**0.5**	Ks	2007											0.0	Fh

Parcel n.	Area (ha)	Area (feddan)	Main species	Planting year	First period			Second period			Third period				Area harvested (ha)	Remarks
					2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
					Area harvested per parcel (ha)											
52b	**0.2**	**0.5**	Si	2002			0.2								0.2	
53	**0.4**	**0.9**	Si	2002			0.4								0.4	
54	**0.4**	**1.0**	Si	2002			0.4								0.4	
55	**0.4**	**0.9**	Si	2002			0.4								0.4	
56	**0.4**	**0.9**	Si	2002		0.4									0.4	Fob
57	**0.8**	**1.8**	Cu	2002			0.8								0.8	Fh, Fob
58	**0.8**	**1.9**	Eca	2008								0.8			0.8	
59	**0.8**	**1.9**	Eca	2008								0.8			0.8	
60a	**0.3**	**0.7**	Eca	2012								0.3			0.3	
60b	**0.4**	**1.0**	Eca	2008								0.4			0.4	
61	**0.7**	**1.7**	Eca	2012											0.0	
62	**0.7**	**1.7**	Eca	2012											0.0	
63	**0.6**	**1.5**	Cu	2002				0.6							0.6	Fh
64	**0.8**	**1.9**	Da	2007											0.0	Fh
65	**0.6**	**1.5**	Ks	2007											0.0	Fh
66	**0.6**	**1.4**	Eci	2010									0.6		0.6	
67a	**0.4**	**0.8**	Unc	0											0.0	
67b	**0.4**	**0.9**	Ks	2007											0.0	Fh
68	**0.7**	**1.6**	Ks	2007											0.0	Fh
69	**0.7**	**1.6**	Ks	2007											0.0	Fh
70	**0.7**	**1.7**	Ks	2007											0.0	Fh
71a	**0.3**	**0.8**	Ks	2007											0.0	Fh
71b	**0.3**	**0.8**	Si	2002			0.3								0.3	
72	**0.7**	**1.6**	Si	2002			0.7								0.7	
73	**0.7**	**1.7**	Si	2002			0.7								0.7	
74	**0.7**	**1.6**	Si	2002		0.7									0.7	
75	**0.7**	**1.7**	Si	2002		0.7									0.7	Fob
76a	**0.3**	**0.8**	Si	2002		0.3									0.3	Fob
76b	**0.2**	**0.4**	Eca	2010											0.0	Fob
77	**0.8**	**1.8**	Cu	2002											0.0	Fh, Con, Fob
78	**0.8**	**1.9**	Unc	0											0.0	
79	**0.8**	**1.9**	Unc	0											0.0	
80	**0.7**	**1.8**	Unc	0											0.0	
81	**0.7**	**1.8**	Pi	2002		0.7									0.7	
82	**0.7**	**1.7**	Pi	2002											0.0	Con
83	**0.6**	**1.5**	Cu	2002				0.6							0.6	Fh
84	**0.8**	**1.8**	Da	2007											0.0	Fh

Parcel n.	Area (ha)	Area (feddan)	Main species	Planting year	First period			Second period			Third period				Area harvested (ha)	Remarks
					2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
					Area harvested per parcel (ha)											
85	**0.6**	**1.5**	Unc	0											0.0	
86	**0.6**	**1.3**	Unc	0											0.0	
87a	**0.4**	**0.9**	Unc	0											0.0	
87b	**0.4**	**0.9**	Ks	2007											0.0	Fh
88	**0.7**	**1.6**	Ks	2007											0.0	Fh
89	**0.6**	**1.5**	Ks	2007											0.0	Fh
90	**0.7**	**1.6**	Ks	2007											0.0	Fh
91a	**0.3**	**0.7**	Ks	2007											0.0	Fh
91b	**0.3**	**0.8**	Si	2002			0.3								0.3	
92	**0.7**	**1.6**	Si	2002			0.7								0.7	
93	**0.7**	**1.6**	Si	2002	0.7										0.7	
94	**0.6**	**1.5**	Si	2002	0.6										0.6	
95	**0.7**	**1.7**	Si	2002	0.7										0.7	
96a	**0.3**	**0.8**	Si	2002	0.3										0.3	
96b	**0.4**	**0.8**	Eca	2010											0.0	Fob
97	**0.5**	**1.2**	Eca	2010											0.0	Fob
98	**0.7**	**1.6**	Cu	2002			0.7								0.7	Fh, Fob
99	**0.7**	**1.6**	Unc	0											0.0	
100	**0.7**	**1.6**	Unc	0											0.0	
101	**0.6**	**1.3**	Unc	0											0.0	
102	**0.5**	**1.2**	Pi	2002		0.5									0.5	
103	**0.5**	**1.2**	Pi	2002		0.5									0.5	
104	**0.4**	**0.9**	Cu	2002				0.4							0.4	Fh
105	**0.5**	**1.2**	Da	2007											0.0	Fh
106	**0.4**	**1.0**	Unc	0											0.0	
107	**0.4**	**0.9**	Unc	0											0.0	
108	**0.5**	**1.2**	Unc	0											0.0	
109	**0.4**	**1.1**	Unc	0											0.0	
110	**0.5**	**1.1**	Ks	2007											0.0	Fh
111	**0.4**	**1.1**	Ks	2007											0.0	Fh
112	**0.4**	**1.0**	Ks	2007											0.0	Fh
113	**0.4**	**0.9**	Si	2002	0.4										0.4	
114	**0.4**	**0.9**	Si	2002	0.4										0.4	
115	**0.4**	**0.8**	Si	2002	0.4										0.4	
116	**0.4**	**0.9**	Si	2002	0.4										0.4	
117a	**0.2**	**0.4**	Si	2002	0.2										0.2	
117b	**0.2**	**0.4**	Eca	2010											0.0	

Parcel n.	Area (ha)	Area (feddan)	Main species	Planting year	First period 2013	First period 2014	First period 2015	Second period 2016	Second period 2017	Second period 2018	Third period 2019	Third period 2020	Third period 2021	Third period 2022	Area harvested (ha)	Remarks
					Area harvested per parcel (ha)											
118	**0.3**	**0.8**	Eca	2010											0.0	Fob
119	**0.1**	**0.3**	Eca	2010											0.0	Fob
120	**1.3**	**3.1**	Cu	2002	1.3										1.3	Fh, Fob
121a	**0.5**	**1.2**	Cu	2002	0.5										0.5	Fh
121b	**0.4**	**1.0**	Te	2005											0.0	Fh
121c	**0.5**	**1.2**	Unc	0											0.0	
122	**1.4**	**3.4**	Te	2005											0.0	Fh
123a	**1.2**	**3.0**	Te	2007											0.0	Fh
123b	**0.1**	**0.3**	Ba	2007											0.0	
124a	**1.0**	**2.4**	Ba	2007											0.0	
124b	**0.4**	**0.9**	Unc	0											0.0	
125	**1.5**	**3.5**	Cu	2002	1.5										1.5	Fh
126	**1.4**	**3.3**	Cu	2002	1.4										1.4	Fh, Fob
127	**1.5**	**3.5**	Eca	2006						1.5					1.5	Fob
128a	**0.9**	**2.2**	Eci	2007						0.9					0.9	Fob
128b	**0.5**	**1.2**	Unc	0											0.0	Fob
129a	**0.7**	**1.6**	Eci	2007						0.7					0.7	Fob
129b	**0.6**	**1.3**	Kg	2010	0.6										0.6	Fob
130	**1.6**	**3.8**	Ca	2006										1.6	1.6	Fob
131a	**0.6**	**1.4**	Ca	2011										0.6	0.6	Fob
131b	**0.7**	**1.7**	Ja	2006											0.0	Fob
132a	**0.7**	**1.6**	Ja	2006											0.0	Fob
132b	**0.8**	**1.9**	Eci	2010								0.8			0.8	Fob
133	**1.4**	**3.2**	Eci	2010								1.4			1.4	Fob
134	**1.4**	**3.3**	Eci	2010											0.0	Fob
135	**2.0**	**4.9**	Eci	2010											0.0	Fob
136	**1.3**	**3.2**	Unc	0											0.0	Fob
137	**1.4**	**3.3**	Unc	0											0.0	Fob
138	**1.4**	**3.3**	Unc	0											0.0	Fob
139	**1.3**	**3.2**	Unc	0											0.0	Fob
140a	**0.1**	**0.3**	Ja	2010											0.0	
140b	**0.1**	**0.3**	Jo	2010											0.0	
140c	**1.0**	**2.4**	Unc	0											0.0	Fob
141	**0.7**	**1.7**	Unc	0											0.0	Fob
142	**0.3**	**0.8**	Unc	0											0.0	Fob
143	**0.4**	**0.9**	Unc	0											0.0	Fob
144	**2.0**	**4.6**	Unc	0											0.0	Fob

Parcel n.	Area (ha)	Area (feddan)	Main species	Planting year	First period			Second period			Third period				Area harvested (ha)	Remarks
					2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
					Area harvested per parcel (ha)											
145	**1.3**	**3.2**	Eci	2008									1.3		1.3	Fob
146	**1.4**	**3.3**	Eci	2008									1.4		1.4	
147	**1.3**	**3.2**	Eci	2008							1.3				1.3	Fob
148a	**1.0**	**2.3**	Eci	2008							1.0				1.0	Fob
148b	**0.4**	**1.0**	Pi	2009		0.4									0.4	Fob
149a	**0.8**	**2.0**	Pi	2009		0.8									0.8	
149b	**0.8**	**2.0**	Eca	2008								0.8			0.8	
150	**1.3**	**3.2**	Eca	2011											0.0	Fob
Tot. Ha	**128.5**	**305.8**														
Real harvested area (ha)					**9.2**	**9.7**	**9.0**	**6.9**	**5.4**	**5.1**	**3.6**	**6.7**	**5.3**	**7.0**	**68.0**	
Regular harvested area (ha)					**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**90.4**	
Difference between real area harvested-regular area (ha)					0.2	0.7	0.0	-2.1	-3.6	-3.9	-5.4	-2.3	-3.7	-2.0	-22.4	

Examples of the HARVESTING PLAN 2013-2022:

Parcel n.	Area (ha)	Area (feddan)	Main species	Planting year	First period			Second period			Third period				Area harvested (ha)	Remarks
					2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
					Area harvested per parcel (ha)											
1	**0.7**	**1.6**	Eci	2010								0.7			0.7	Fob

Figure 17: Example HARVESTING PLAN 2013-2022, Parcel 1.

Parcel 1:

-It has an area of 0.7 ha (1.6 feddan).

-The main species is *Eucalyptus citriodora* (Eci).

-It has been planted in the year 2010.

-In the year 2020 it is recommended to harvest the entire parcel area (0.7 ha).

-In the year 2020, after the harvesting, it is recommended to replant the entire parcel with Eucalyptus citriodora (indicated with green color).

-*Area harvested per parcel (ha)* indicates if the entire parcel shall be harvested or only parts of it. In this example the entire parcel shall be cut (0.7ha)

-*Area harvested (ha)* would sum the harvested areas of one parcel if harvesting would have been scheduled for different years.

-*Remarks:* The parcel is situated at the edge of the plantation. For wind protection purposes a strong forest border (Fob) shall be developed by planting shrubs and Casuarina trees towards the desert side of the parcel (see map 3 and chapter "General zoning of the plantation area").

Parcel n.	Area (ha)	Area (feddan)	Main species	Planting year	First period			Second period			Third period				Area harvested (ha)	Remarks
					2013	2014	2015	2016	2017	2018	2019	2020	2021	2022		
					Area harvested per parcel (ha)											
1	**0.7**	**1.6**	Eci	2010								0.7			0.7	Fob
...	**.....**	**.....**	.....	....	..	..	..	..	..	..	..	..	..	..	....	...
...	**.....**	**.....**	.....	....	..	..	..	..	..	..	..	..	..	..	....	...
Tot. Ha	128.5	305.8														
Real harvested area (ha)					**9.2**	**9.7**	**9.0**	**6.9**	**5.4**	**5.1**	**3.6**	**6.7**	**5.3**	**7.0**	**68.0**	
Regular harvested area (ha)					**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**9.0**	**90.4**	
Difference between real area harvested-regular area (ha)					0.2	0.6	0.0	-2.2	-3.6	-4.0	-5.4	-2.3	-3.7	-2.0	-22.8	

Figure 18: Example HARVESTING PLAN 2013-2022, harvested areas.

Year 2013 (first planning period):

-*Real harvested area (ha)* is the total area recommended to be harvested in the respective year. In the case of the year 2013 the area of the parcels that shall be harvested sum up to 9.2 ha (Also Sisal parcels are regarded to be "harvested").

-*Regular harvested area (ha)* is the area of the regular annual yield for the entire plantation which is calculated to be 9.0 ha/year.

-*Difference between real area harvested-regular area (ha)* is the difference between the total area recommended to be harvested in the respective year and the regular annual yield for the entire plantation in the same year. In the year 2013 0.2 ha are more harvested than expected.

Inter-institutional and socio-economic management recommendations

The socio-economic aspect plays an important role in sustainable forest management. The socio-economic objectives are directly linked to and are of equal importance as the silvicultural objectives. As a consequence a good socio-economic management is of the same relevance than silvicultural management. Management recommendations are described in the following to reach the objectives of sustainable forest management. The implementation requires inter-institutional efforts to solve the problems and threats.

Change in forest management responsibilities and decision making processes

Based on the observation that decision making structures are impeding silvicultural success and flexibility at the plantation the following actions should be considered by the authorities within the involved institutions:

- It is important to establish general planning, reporting and control mechanisms between and within the institutions. This system of planning and reporting can be based on a regular annual period of planning, management and reporting. It is not recommendable that managers of the Institutions are involved in ad hoc silvicultural decisions or that committees are formed for this purpose.
- A committee composed by the involved institutions and guided by the MALR and the UAE, should formulate concrete targets for the plantations (silvicultural production targets, economic targets, social targets, ecological targets).
- The set targets for each period must be brought into action and tried to be achieved by the UAE and the plantation managers At certain stages of the planning period a report about the activities should show the results strengths and weaknesses of the activities. Every involved part of the institutions therefore needs its clearly defined responsibilities.
- Under the general supervision of the UAE and within the planning framework the plantation managers should be provided with more authorization and freedom for silvicultural decisions to achieve the set targets and to be able to react flexible on occurring needs. At the end of a planning period the plantation management with the facilitation of the UAE has to report and to justify its activities.
- The research institution should have an advisory role to enable the definition of the targets. Their expertise should be requested by the UAE and the plantation managers for silvicultural decisions but not for the decision itself.

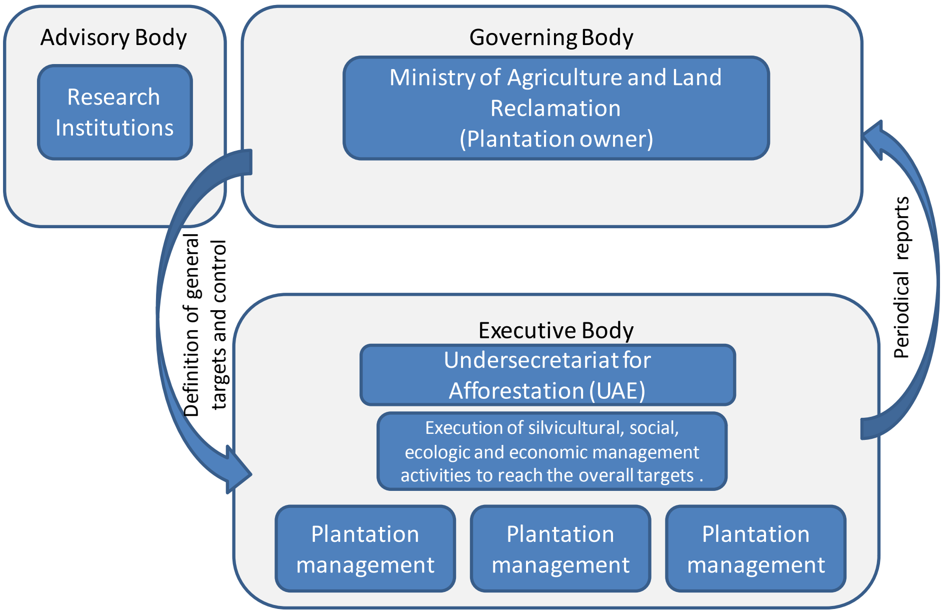


Figure 19: Institutional relations for the development of clear responsibilities

Development of a market strategy

One purpose of the Serapium forest is to produce wood for the national wood market. But this objective is only loosely formulated and the silvicultural treatments are not oriented to produce for market demands. To find the best cost benefit ratio of the resource allocation and to improve economic results as well as to help defining production targets a market analysis must be carried out. Questions that must be addressed are:

- ✓Which qualities are demanded at the local market in Ismailia region (what are the real end uses of the current wood products)?
- ✓Which prices can be achieved with higher quality wood?
- ✓Is the produced quantity and quality enough to access other markets?
- ✓Are there other selling options with (national) wood buying companies (considering quality and quantity)?

When these questions are clarified the production at the plantation can be adjusted and the respective silvicultural measures can be implemented (e.g. longer or shorter rotations, higher or lower commercial diameters, biomass production with higher tree densities, etc.).

Research

The authorities should take immediate action to **assess the health risks due to pathogens and heavy metals in TWW and plant material**. If pathogens are still in the TWW and if heavy metal contents in animal tissue and organs are found to be too high then the access to the plantation must be immediately restricted. The local population must be informed about the health risks in any case.

Silvicultural research activities should not only focus on species trials with seedling and growth experiments, but should also realize scientifically elaborated experiments of different silvicultural treatment of existing species and stands. The investigation of growth and yield parameters is important for future decisions and internal statistics.

Conflict management with the local population

The UAE and the plantation management should work on a solution of the problems with the local population with the support of the Ministry of Agriculture. A segregative approach would be to fence off and protect the plantation area from unauthorized access. This would mean to invest in fencing material, but would stop browsing and other unauthorized activities in the plantation immediately. At the same time the denial of land use practices and access to resources could be taken as an offence by the local population. An integrating approach would include initiatives to inform the local population more about the purpose and the silvicultural production goals of the other functions of the forest plantation. The local population must also be informed about the risks of heavy metals and other health risks due to the irrigation with TWW. The initiative should focus on inviting the local population to round table discussions to find mutual consensus and strategies so that every stakeholder gets his interests respected. A solution could be that animal owners commit themselves to control and observe their animals when the plantation administration grants animal feeding in certain areas and on plants that are not foreseen for wood production. This option must be well prepared and would need a longer enduring process. In case future research shows, that the content of heavy metals is a real health risk, then the authorities should prefer the first solution to fence the area and deny access.

Capacity building

The forest strategy from the MALR (2009) states that capacity building at all levels is a main issue to strengthen the forest sector in Egypt. Silvicultural knowledge as well as silvicultural management planning and skills for ministry employers, plantation managers and workers should be improved. The network of associated organizations and institutions on national and international level should spare no efforts to exchange knowledge in the field of forest management. A training centre could be established in Serapium forest. Recommendations for training programs are:

- Forest management, planning and monitoring
- Silvicultural treatments and techniques for sustainable management and for better wood quality (Pruning, Thinning, Harvesting)
- Planning and implementation of forest inventories, forest mapping and forest data analysis
- Marketing and market strategies for wood products
- Safety course for forest workers
- Wood technology and wood quality
- Pathology of trees
- Training of future forest trainers
- Irrigation planning

Water management

Due to low rainfall in the region (24mm/year) and the shortage of treated waste water provided to the plants (breakdown of five pumps from seven), water is by far the biggest constraint to the survival of the Serapium plantation.

The following actions are required while considering water management issues in the plantation:

- **The most immediate need is to urgently fix the pumping system in order to restore the irrigation scheme to the originally planned 16 hours of irrigation per parcel, per month.**
- The plantation administration should estimate, with the support of specialized technicians, the actual amount of water provided to the plants in order to formulate a more accurate water management plan, capable of satisfying the water requirements of the different tree species
- A possible expansion of the forest surface can only be achieved through a better design and construction of the pumping system and irrigation scheme, customized for the use of TWW and for the extension. The current layout was originally designed to be used with clean water and accommodate the needs of the current irrigated surface. Therefore is not meant to withstand long wearing caused by TWW residues and does not provide enough water for the entire area.

As long as the main pumps have not enough power to guarantee enough pressure in the 3rd level pipes, the irrigation technicians have to find new solutions to guarantee homogeneous water supply until the parcel margins. One option to improve irrigation in the parcels could be to redesign the pipe system within the parcels. At the moment the 18mm 3rd level pipes are too long and water pressure declines to the end. The effect is lower water supply at the parcel margins. The following figure proposes to establish two 2nd level pipes in each parcel to shorten the 3rd level pipes.

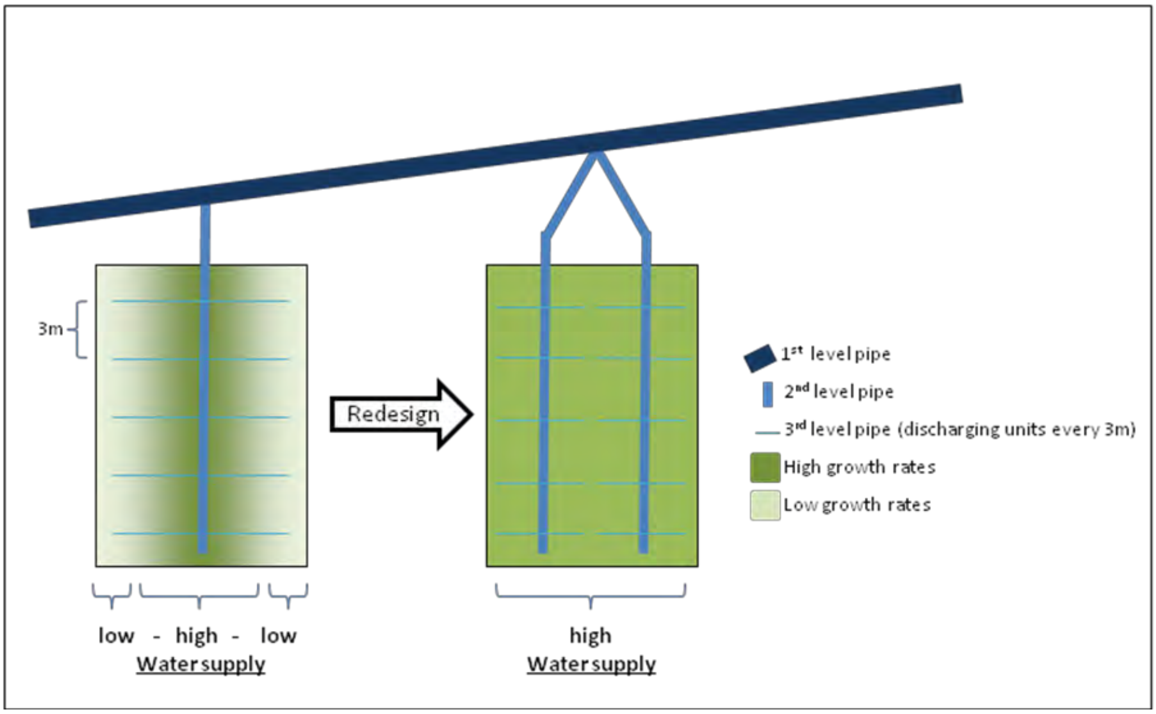


Figure 20: Option for redesign of the pipe system for homogeneous water supply in the parcels.

Documentation

Documentation of all activities at the plantation is the task of the plantation manager and is essential for further forest management planning and reporting. The plantation history will help scientists, foresters and future plantation managers to develop future activities. UAE and plantation management should establish logic and structured documentation for:

–Silvicultural activities per parcel (planting, thinning, harvested volume, etc.)
–Irrigation timing and quantity per parcel and in total
–Occasional incidents (per parcel or concerning the whole plantation)

Advantageous is the developed parcel enumeration. UAE can develop a data base (for instance using existing GIS data from the project) for each plantation where activities will be reported directly linked to a parcel number.

4. Perspectives

Forest area for CO_2-Fixation (Carbon credit market)

An interesting opportunity for the extension of the plantation surface is related to the use of the voluntary carbon credit market. Private companies and big emitters may be willing to acquire carbon credits by financing new afforestation activities and the resulting reduction of CO_2 emissions. Such carbon credits have a corresponding fixed economic value, associated with the level of carbon stocked in plants during growth, which can be exchanged in a specific market (AZZERO CO_2 2012).

Afforested areas must satisfy certain requirements to qualify for the carbon credit market schemes:

- The minimum required area is 4-5ha.
- The area must be additional to already planned or existing forest areas and should not have been covered by forest for at least 10 years.
- The employed tree species must be native or naturalized in the country and shall reach at least 5 meters of height in situ.
- Monoculture parcels are prohibited. At least 2-3 species with good growth rates should be planted (e.g. Eucalyptus citriodora, Eucalyptus camaldulensis, Casuarina equisetifolia).
- Rotation length must be minimum 10 to 20 years;
- Harvesting is allowed at the end of the contract period but the stored carbon should be fixed in wood products (e. g. furniture).
- Forest health must be guaranteed and dead individuals must be replanted in the first years.

Based on the requirements set above and a preliminary study carried out in the Italian voluntary carbon credit market, the following opportunities for funding have been identified:

Table 23: Potential revenues gained from additional forest areas through CO_2 fixation (AZZERO CO_2 2012).

Rotation length (years)	Optional size for Afforestation areas (ha)	Potential revenues for afforestation projects from the carbon credit market (per indicated area)	
		E£ (EGP, Egyptian pound)	US $
10 years	5	118683	19357
	10	237410	38721
15 years	5	138469	22584
	10	276976	45174
20 years	5	158273	25814
	10	316547	51628

5. Conclusion

Serapium forest plantation provides evidence that it is possible to establish and manage productive forest plantations in a desert setting using waste water for irrigation. The increase of the cultivated forest area during the last years at Serapium and the results of the inventory show the impressive efforts of the plantation management and the work of the UAE. Forest management is always confronted with challenging situations in particular under the difficult site conditions in Egypt. However, the challenges and threats identified in the FMP are considered opportunities for further improvements of the forest plantations.

A priority should be placed on the repair and improvement of the irrigation system. If the pumps will not be repaired the current forest area cannot be maintained shrink and the set objectives will not be achieved. The Inventory results indicate that some trees suffer severe drought stress and many have already died or will die if the situation does not improve. On the other hand, the inventory results also show that the potential for wood production is reasonably high considering the extreme site conditions. However wood production should be adopted to these conditions and aim at the production of general utility timber with suitable species rather than trying to produce timber for the high-end market with species that are not adapted to grow well under the specific site conditions.

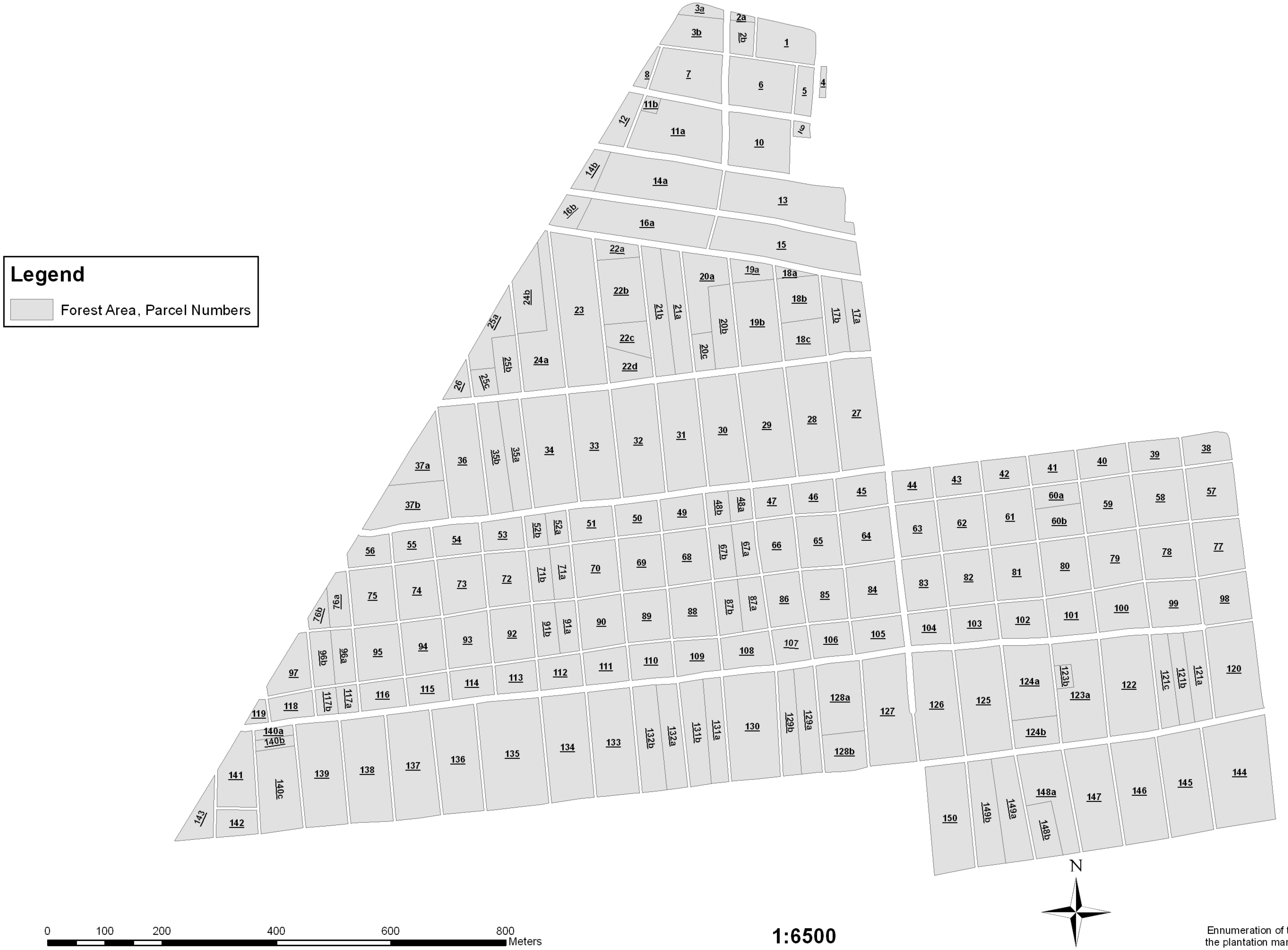
Responsible managers should adapt the objectives of the plantation to the real situation and a realistic market strategy should be developed. The plantation management should focus on successful species and should not maintain species with lower increments. It is important to implement the recommended silvicultural interventions as explained in this FMP, consisting of the **WOOD PRODUCTION SCHEME IN 5 STEPS** and the **HARVESTING PLAN 2013-2022**.

The strength of the plantation is supply local markets with normal wood qualities which should be produced in relatively short rotations to guarantee regular yields over the next years. At the same time it offers job opportunities and an environment for capacity building in forest management, research and outreach to local communities. Another priority is the urgent investigation of possible health risks for animals which browse on plants possibly contaminated with heavy metals. It is further recommended to professionally monitor the management of the forest plantations in cooperation with national research institutions, to record the harvested volumes and the replanting of the harvested areas.

The Continuous commitment of all involved authorities and institutions will find ways and means to address these problems and to help the plantation management to implement the silvicultural techniques described in the management plan. Continuous training activities in silviculture and management planning are an opportunity for all involved institutions to strengthen the forest sector in Egypt.

ANNEX

Serapium Forest, Ismailia - Forest Area with Parcel Numbers



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20. November 2012
Ennumeration of the parcels in agreement with
the plantation management of Serapium forest.

Map 2

Serapium Forest, Ismailia - Tree Species Distribution 2012

20. November 2012
Food and Agriculture Organization of the United Nations (FAO).
Information from the Undersecretariat for Afforestation, Egypt,
and a forest inventory in September. The map was created using
'Bing Maps Aerial' provided by ESRI ArcView10.
The designations employed and the presentation of material in the map
do not imply the expression of any opinion whatsoever on the part of FAO
concerning the legal or constitutional status of any country, territory or
sea area, or concerning the delimitation of frontiers.

Map 3

Serapium Forest, Ismailia - Forest Functions 2013 - 2022

Legend

Water Basins

ForestFunction

- Demonstration Forest
- Experimental Area
- Productive Forest
- Protective Forest
- Roads
- Buildings
- Nursery

Forest Area (Parcel Number)

Dominant Species (Planting Year)

- Bambus
- Casuarina equisetifolia
- Cupressus sempervirens
- Dalbergia sissoo
- Eucalyptus camaldulensis
- Eucalyptus citriodora
- Harpullia
- Jatropha curcas
- Jojoba (Simmondsia chinensis)
- Khaya grandifoliola
- Khaya senegalensis
- Pinus halepensis
- Sisal (Agave sisalana)
- Terminalia arjuna
- Uncultivated

0 100 200 400 600 800 Meter

1:6500

20. November 2012
Food and Agriculture Organization of the United Nations (FAO).
Information from the Undersecretariat for Afforestation, Egypt,
and a forest inventory in September. The map was created using
'Bing Maps Aerial' provided by ESRI ArcView10.
The designations employed and the presentation of material in the map
do not imply the expression of any opinion whatsoever on the part of FAO
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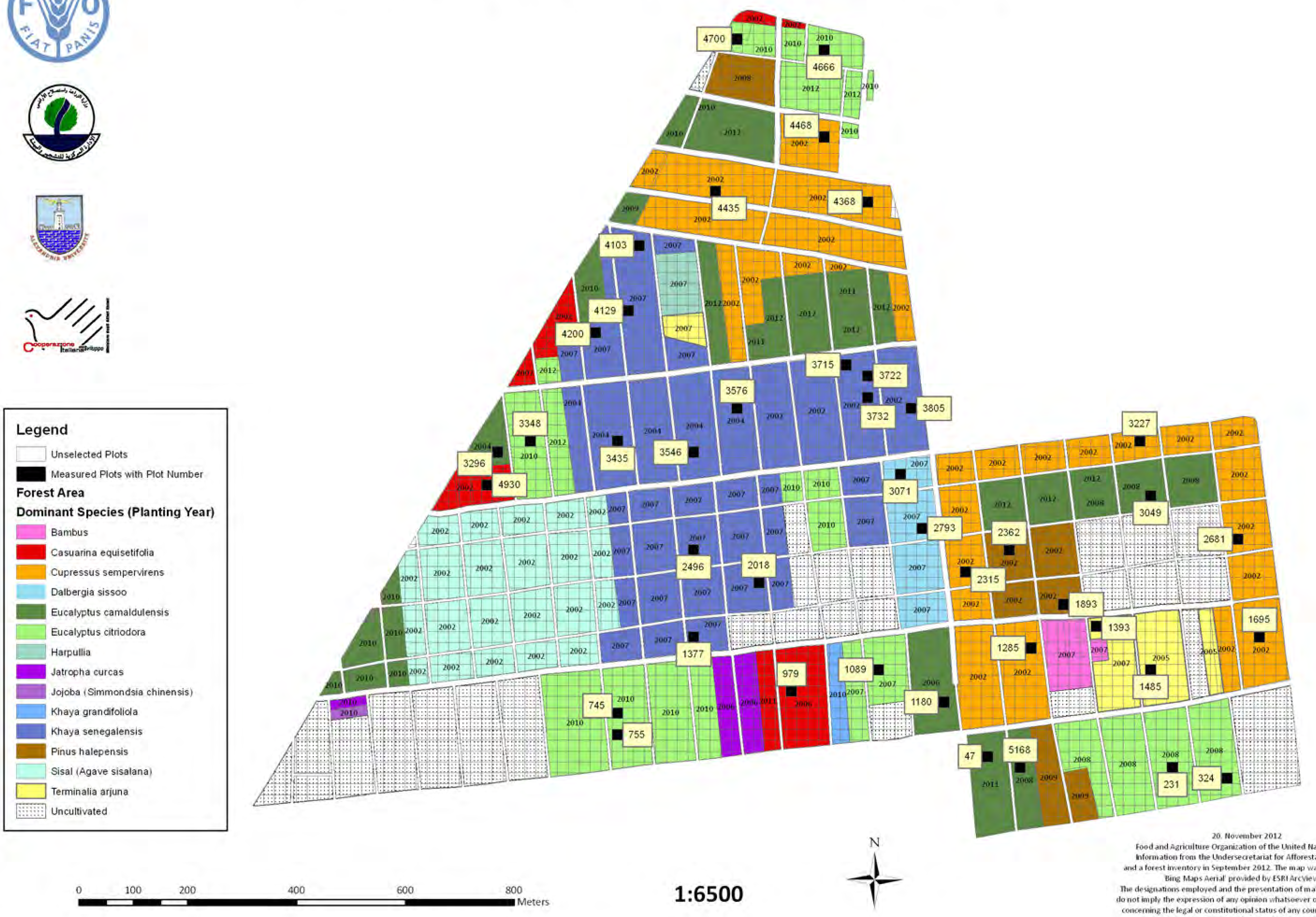
sea area, or concerning the delimitation of frontiers.

Serapium Forest Ismailia - Sample Plots Forest Inventory 2012



20. November 2012
Food and Agriculture Organization of the United Nations (FAO).
Information from the Undersecretariat for Afforestation, Egypt,
and a forest inventory in September 2012. The map was created using
'Bing Maps Aerial' provided by ESRI ArcView10.
The designations employed and the presentation of material in the map
do not imply the expression of any opinion whatsoever on the part of FAO
concerning the legal or constitutional status of any country, territory or
sea area, or concerning the delimitation of frontiers.

Table 24: Overview Stakeholder Analysis Serapium Forest, Ismailia, 2012:PUBLIC SECTOR

Stakeholder: Role and function.	Present at the workshop	Relation to, and interest in the plantation.	Primary objectives.	Positive influence on the plantation.	Negative influence on the plantation (Problem caused by stakeholder).	Degree of problem	Ability and motivation to solve problems.	Notes
Ministry of Agriculture & Land Reclamation	No	Owner of the plantation	-Environment; -Wood production	Funding	Decision processes take too long (committees) and cause delays of necessary actions in the plantation.	High	A change in decision structures is regarded as difficult.	An overall accepted system of forest information, planning and reporting could help the plantation management.
Undersecretariat for Afforestation (UAE) + Plantation Management	Yes	Management of the plantation	Sustainable management according to objectives	-Funding; -Professional support; -Cooperation with external partners	Limited responsibilities and authorizations in funding and silvicultural measures.	High	A change in structures is regarded as difficult.	Dependency on the decision structures with the Ministry of Agriculture and Land Reclamation.
Ministry of Housing, Utilities and Urban Development	No	Provision of the treated waste water (TWW)	Treatment of waste water	-No costs for the TWW; -No limits in quantity	Alternating water quality	Low	---	---
Agriculture Research Center	Yes	Research	Research	-New knowledge and knowledge exchange with UAE and plantation management	---	---	---	Missing practical field work for students;
Governorate of Ismailia	No	---	---	Common provision of drinking water and electricity	No support like in other local governorates (e.g. in Luxor)	Low	---	---
Police	No	---	Security	---	Limited activity and help in case of theft	Low	---	---
Fire department	No	---	---	Fast help when needed	---	---	---	---

Table 25: Overview Stakeholder Analysis Serapium Forest, Ismailia, 2012: WORKERS & PRIVATE SECTOR

Stakeholder: Role and function.	Present at the workshop	Relation to, and interest in the plantation.	Primary objectives.	Positive influence on the plantation.	Negative influence on the plantation (Problem caused by stakeholder).	Degree of problem	Ability and motivation to solve problems.	Notes
Workers (39) -Forest workers (10) -Irrigation (7) -Nursery (1) -Electricity (1) -Mechanic (1) -Driver (3) - Security guard (16)	Yes (3)	Regular employees	-earn money; -fulfill the requirements of the duty	-Accomplishment of tasks, given by the plantation management	-workflows; -level of professional skills may lead to lower results; -motivation;	Medium	High motivation for further trainings	More training in silviculture, cutting and harvesting techniques for all workers, could help to build up a crew of well trained all-round professional workers.
Local settlers (Badu) (200-300)	No	-live in the surrounding areas; - claim indigenous rights of land use (?)	-feed animals; -construction- and fuel material;	---	-Uncontrolled BROWSING; -cutting of trees; -theft of equipment; -shortcuts through the plantation; -intimidation of workers and plantation management (armed Bedouins)	High	Low motivation (at the moment their demands are met)	-There is the need that ministries and UAE acknowledge the problems find a way to solve them. -More information for the local population about the plantation and awareness rising about the problems.
Harvesting companies (4, Fayed)	No	Buy and harvest wood	Business	---	-Harvesting operations carried out by company, observed by plantation workers, although the plantation workers would be capable of doing it themselves.	---	High motivation among the management and among the workers to plan and conduct harvesting processes.	-Own harvesting would use the capacities of the workers. -Thinnings should be conducted by plantation workers for quality reasons and to avoid damage on the remaining stand and/or the irrigation system

Irrigation company (Fayed)	No	Contracted for the establishment or maintenance of irrigation tubes if needed.	Business	In general good quality of the work.	-delay in contracts; - missing adaption to needs of a forest plantation	Medium		Good planning, better communication of the needs and better contracts could help to achieve better results.
Pump company (Cairo)	No	Contracted for maintenance if needed.	Business	Good quality	-No emergency arrangement if pumps break totally and help is needed suddenly	High		Emergency planning must be guided by decision makers in Cairo, involving pump company.

Table 26: Overview Products and Markets Serapium Forest, Ismailia

Product	Quality parameters	Minimum quantity for sale	Price per unit4 (fresh wood)	Potential use	Notes
CASUARINA EQUISETIFOLIA					
Timber (high quality)	Ø>15cm h=1.2m/2.2m/... straight, branchless	>6t	200-300E£/t	furniture	---
Timber (low quality)	Ø>5cm	>6t	120-150E£/t	-fuel wood -charcoal	---
Poles and stakes	Ø 5cm h>2.5m	400pieces	1-2E£/piece	banana or grape plantations	Underutilized wood product
CUPRESSUS SEMPERVIRENS					
Timber (high quality)	Ø>11cm h=1.2m/2.2m/... straight, branchless	>6t	350E£/t	-furniture; -ship construction -carvings	---
Timber (low quality)	Ø>5cm	>6t	80-100E£/t	-fuel wood -charcoal	---
DALBERGIA SISSOO					
Timber (low quality)	---	---	---	-carvings -furniture	-no sales experience
EUCALYPTUS CAMALDULENSIS AND EUCALYPTUS CITRIODORA					
Timber (high quality)	Ø>15cm h=1.2m/2.2m/... straight, branchless	>6t	200-300E£/t	furniture (local)	---
Timber (low quality)	Ø>5cm	>6t	120-150E£/t	-fuel wood -charcoal	---
Poles and stakes	Ø 5cm h>2.5m	400pieces	1-2E£/piece	banana or grape plantations	Underutilized wood product
KHAYA SENEGALENSIS					
Timber (high quality)	---	---	---	-furniture (-veneer)	-no sales experience
Timber (low quality)	---	---	---	-fuel wood -charcoal -carvings	-no sales experience
PINUS HALEPENSIS					
Timber (low quality)	---	---	---	-fuel wood -charcoal	---
TERMINALIA ARJUNA					
Timber (low quality)	---	---	---	---	-no sales experience
OTHER					
Needles and leaves	---	---	---	-compost -component for cement for lighter construction	-Research needed

[4] 1 E£ (EGP, Egyptian pound) = 0,16 US $ (20.11.2012)

Bibliography

Ayling, R.D; Martins, P.J (1981): The growing of eucalypts on short rotation in Brazil. In: The Forestry Chronicle (57(1)), p. 9–16.

AzzeroCO2 – Energy Service Company. Rome, Italy: Personal communication with Elena Piazza & Luca Loperfido (26.11.2012).

CABI (2012 a): Forestry Compendium database report - Casuarina equisetifolia. http://www.cabi.org/fc/ (06. September 2012).

CABI (2012 b): Forestry Compendium database report - Eucalyptus camaldulensis. http://www.cabi.org/fc/ (06. September 2012)

CABI (2012 c): Forestry Compendium database report - Eucalyptus citriodora. http://www.cabi.org/fc/ (06. September 2012)

CABI (2012 d): Forestry Compendium database report - Khaya senegalensis. http://www.cabi.org/fc/ (06. September 2012)

CABI (2012 e): Forestry Compendium database report – Pinus halepensis. http://www.cabi.org/fc/ (06. September 2012)

Clément, J. (1982): Estimation des volumes et de la productivité des formations mixtes forestières et graminéennes tropicales. Données concernant les pays de l'Afrique francophone au nord de l'Equateur et recommandations pour la conduite de nouvelles études. In: Bois et forêts des Tropiques (198), p. 35–58.

Council of the European Union (04.05.1999): COUNCIL DIRECTIVE 1999/29/EC of 22 April 1999 on the undesirable substances and products in animal nutrition. 1999/29/EC. Official Journal of the European Communities. http://eur-lex.europa.eu

El-Kateb (2012, personal communication): Growth potential of Eucalyptus citriodora, Eucalyptus camaldulensis, and Khaya senegalensis in Ismailia and Sadaat City. Technische Universität München (TUM).

El-Osta, M.L.M; Megahed, M.M; El-Lakany, M. H.; Hegazy, S.S (1992): Estimates of Above-Ground Biomass for Casuarina Windbreak Trees in Northwestern Region of Egypt. In: Alexandria Journal of Agricultural Research (37(3)), p. 57–83.

Evett, Steven R.; Zalesny Jr., Ronald S.; Kandil, Nabil F.; Stanturf, John A.; Soriano, Chris (2011): Opportunities for Woody Crop Production using Treated Wastewater in Egypt. II. Irrigation Strategies. In: International Journal of Phytoremediation (13 (S1)), p. 122–139.

Evans, Julian (1992): Plantation Forestry in the Tropics (2^{nd} edn.): Tree Planting for Industrial, Social, Environmental and Agroforestry Purposes.

FAO AQUASTAT. FAO's Information System on Water and Agriculture: Climate Information tool. AQUASTAT Climate characteristics. http://www.fao.org/nr/water/aquastat/gis/index3.stm (04. October 2012).

FAO (1981): Eucalyptus for Planting (2^{nd} revised and extended edition, 1^{st} edition 1955). FAO Forestry Series 11.

FAO (1992): Wastewater Treatment and Use in Agriculture. FAO Irrigation and Drainage Paper 47.

FAO (2001): Global Forest Resources Assessment 2000. Main report. FAO Forestry Paper 140.

FAO (2002): Near East Forestry Commission - 15th Session. Item 6 of the Provisional Agenda. The Use of Treated Waste Water (TWW) in Forest Plantations in the Near East Region. Secretariat Note. Khartoum, Sudan.

FAO (2010a): Global Forest Resources Assessment 2010. Country Report Egypt.

FAO (2010b): Global Forest Resources Assessment 2010. Main Report. FAO Forestry Paper 163.

FAO (2011a): Country Pasture/Forage Resource Profiles. Egypt.

FAO (2011b): Assessing forest degradation. Towards the development of globally applicable guidelines. Forest Resources Assessment Working Paper 177.

FAO (2012): Serapium Forest Ismailia, Egypt: Manual for Integrated Field Data Collection for the Forest Management Plan 2013-2022. Project working document 2 (GCP/RAB/013/ITA). http://www.fao.org/forestry/tww/en/.

Farahat, Emad; Linderholm, Hans W. (2012): Ecological Impacts of Desert Plantation Forests on Biodiversity. In: African Journal of Ecology, p. 1–11.

Ghorab, S. A. S.; Ismail, M. F. M.; El-Sayied, S. S. (2011): Phytoremediation of heavy metals by four hyper accumulation timber tree species irrigated with treated waste water. (1)Concentrations of heavy metals in tree parts and soil depths. In: Agricultural Research Journal, Suez Canal University (11 (2)), p. 117–128.

Gibson, A.; Bachelard, E. P.; Hubick, K.T (1995): Relationship between Climate and Provenance Variation in Eucalyptus camaldulensis Dehnh. In: Australien Journal of Plant Physiology (22), p. 453–460.

Knoke, Thomas; Schneider, Thomas; Hahn, Andreas; Griess, Verena C.; Rößiger, Jörg (2012): Forstbetriebsplanung.

Ministry of Agriculture and Land Reclamation, Egypt (MALR); Undersecretariat for Afforestation and Environment (UAE) (2009): Arab Republic of Egypt. Forest Policy and Strategy.

Ministry of State for Environmental Affairs (MSEA); Egyptian Environmental Affairs Agency (EEAA); Egyptian Pollution Abatement Project (EPAP) (2003): Self Monitoring Manual - Waste Water Management.

Ministry of State for Environmental Affairs (MSEA) (2004): Innovative Approach to Municipal Waste Water Management - The Egyptian Experience.

Nouvellet, Y. (2002): Manuel d'aménagement forestier. Rapport sed/ccl, Ministère des mines et de l'énergie et Ministère de l'équipement rural et de l'environnement du Mali. Stratégie Energie Domestique, Cellule Combustibles Ligneux. Bamako, Mali.

Pinyopusarerk, Khongsak; House, Alan Pennock Newton (1993): Casuarina: An Annotated Bibliography of C. equisetifolia, C. junghuhniana and C. oligodon. Nairobi, Kenya.

Tabacchi, Giovanni; Di Cosmo, Lucio; Gasparini, Patrizia; Morelli, Stefano (2011): Stima del volume e della fitomassa delle principale specie forestali italiane. Equazioni di previsione, tavole del volume e tavole della fitomassa arborea epigea. Consiglio per la Ricerca e la sperimentazione in Agricoltura, Unita di Ricerca per il Monitoraggio e la Pianificazione Forestale.

Richardson, Stanley Dennis (1990): Forests and Forestry in China. Changing Patterns of Resource Development.

Röhrig, Ernst; Bartsch, Norbert; Lüpke, Burghard von (2006): Waldbau auf ökologischer Grundlage (7th edition).

UAE (2012 unpublished): Interim Report On Dendrometry And Ecological Collected Data Concerning Sarabium Man-Made Timber Forest.

Wahaab Abdel, Rifaat; Omar El-Din, Mohy (no year): Wastewater Reuse in Egypt: Opportunities and Challenges.

Weinland, Gerd; Zuheidi, Ahmad; Kollert, Walter (1995, unpublished book manuscript): Managing Quality Timber Tree Plantations in Pensinsular Malaysia. Kuala Lumpur, Malaysia.

Zöhrer, Fritz (1980): Forstinventur. Ein Leitfaden für Studium und Praxis. Pareys Studientexte 26.