Swedish University of Agricultural Sciences
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Horticulture

Agroforestry in south of Kurdistan

- with focus on improving soil organic matter and soil structure

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Trädgårdsingenjörsprogrammet – odling
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Agroforestry i södra Kurdistan

- med fokus på att höja halten av organiskt material samt förbättra jordstrukturen.

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- with focus on improving soil organic matter and soil structure.

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Preface

I would like to thank my mentor Helena Karlén for believing in my project and supporting me with valuable thoughts and ideas. Also I would like to thank Inspektor Arvid Gustafssons stiftelse for the scholarship that made this project and essay possible. I would like to express gratitude towards the people in Kurdistan, who welcomed me so cordially and spent much of their effort to help me implement this project. Especially Germiyan Administration Supervisor Salahadin Muhammed Faraj and the Chief of Kalar municipality Jwad Wadi Saeed but also Abdul Karim Mohammed who all three helped me to a place to stay, material to realize my ideas and land to implement them. I wish to thank Victoria Andersson who personally worked with me in the field, and shared all my experiences in Kurdistan in an exemplary way. The person I owe my biggest gratitude to is Kalida Mohammed, who is the founder of the journey to Kurdistan. Kalida inspired me to take on this task and to challenge myself by accepting this project.

2012-05-14 Magnus Johansson

Summary

The area in and around Iraq is formerly known as Mesopotamia and is the birthplace of agriculture. The agriculture in south of Kurdistan, northern Iraq, is today being threatened by drought and depletion, and access to knowledge is limited in these regions. How can agriculture develop in the future without making too big impact on the environment?

The main question was in *what ways is it possible to use multifunctional plant species for increasing soil organic matter and improving soil structure* in Kurdistan? Growing trees, shrubs and crops together and sometimes in combination with livestock is called agroforestry. Agroforestry can be divided in several systems where alley cropping was chosen due to its ability to be applied to farms of both small and big size.

Trees and shrubs *can* be used to improve soil structure and increase soil organic matter. By pruning woody plants and add to the soil as litter or mulch it can increase the soil organic matter. Roots contribute with organic matter when penetrating the soil. Trees with a higher production of biomass should be chosen since they give a higher amount of litter that could be added to the soil. One thing that became clear was that no matter what species of trees were used, the soil organic matter increased when mulching.

The outcome of these investigations showed that some of the keys to long-time fertility were to carefully select what species is the most suitable for the goal at the chosen site. In this case I found that *Punica granatum* and *Carissa edulis* was the best choice of lignified species at my site. These species were chosen mostly because of the adaption to the arid climate but also due to the difficulty to find other multifunctional species. Evergreen trees in arid areas use a lot of water, why species like *Eucalyptus* should be avoided in agroforestry systems.

Hopefully this written thesis will be an inspiration for farmers that wish to sustain their soil fertility and increase biodiversity, and to do so in *line* with nature instead of depleting the soil. I wish my thesis will gain and inspirit the Kurdish people whom I have gotten so much inspiration and love from in return.

Keywords: agroforestry, alley cropping, improve soil organic matter, Kurdistan, soil structure.

باشووری کوردستان، لە کۆندا ناسراو بە میزوپوتامیا، وەک یەکەمین جێگای کشتوکاڵ دەژمێردرێت. ئەمڕۆ کشتوکاڵ لە باشووری کوردستاندا هەڕەشەی لە سەرە بە هۆکاری وشک بوون و بارگرانی گۆی زەوی، و سنووردارییی گەیشتن بە وێژەی نووسراو. چۆن کشتوکاڵ لەو ناوچەیەدا لە پاشەڕۆژدا پێشدەخرێت بەبێ ئەوەی کارتێکردنێکی گەورە لەسەر ژینگە بکرێت؟ چاوەکانم بۆ ئەو کێشانەم کردنەوە و بە رێگای پڕۆژەیەکی قوتابیان بڕیارم دا بچم بۆ ئەو بەشەی کوردستانی عێراق بۆ ئەوەی لە نزیکەوە کێشەکە بخوێنمەوە.

کاری سەرەکیم ئەوە بوو تواناکانی چاندنی بەروبوومی بەکەڵکهاتوو بزانم بۆ ئەوەی ئەندازەی بەرزبکەمەوە و پێکهاتەکەی باشتربکرێت. چاندنی درەخت، دەوەن و دانەوێلە لە گەڵ هەندێ ئاژەڵ لە ژێر ناوی **گشتوکاڵیدارستانەکان** دا دەکرێت. **گشتوکاڵیدارستانەکان** لە سەر چەند جۆرە بەشێکی تەکنیکی دابەش دەکرێن تیایاندا چاندنی هێڵەیی کونجاوترین یانە بۆ ئەم پڕۆژەیە.

بەرهەمهێنانێکی زۆر لە یەکەبایلۆجیەکان رێژەیەکی زیاتری کەرەستەی ئورگانیک دەدات، کە دەتوانرێت لە خاکدا بەکاربهێنرێت بۆ ئەوەی پێکهاتەی زەوی و رێژەی کەرەستە ئورگیەکان پێیان بەرزبکرێتەوە. گەڵا، لق و ڕەگەکان توانای کارکردنی ئەرێنیان لە سەر

پێکهاته و ڕێژەی گڵ هەیە. ئەنجامێکی ئاشکرا ئەوەیە کە جیا لە بەشە بەکارهێنراوەکانی درەختەکان ڕێژەی کەرەستەی ئورگانی لە خاکدا زیاد دەبێت، هەر جۆنێک بێت لەو جێگایەی نخاوتنی خاک بەکارهێنراوە.

دەرئەنجامی ئەم لێکۆڵینەویە دەریخستووە کە کلیلی خاکێکی بە پیتی دڕێژخایەن ئەویە کە بە وردی جۆرەکانی گونجاو بۆ ئامانجەکە لە جێگا دیاریکراوەکەدا هەڵبژێردرێن. لەم بوارەدا بینیم کە Punica granatum (هەنار) و Carissa edulis باشترین جۆری کەرەستەی هەڵبژاردراون. هۆکاری هەڵبژاردنەکەش بۆ توانای شێوەیەک لە بەرگریکردنیان بۆ وشکایەتیی دەگەڕێتەوە، هەروەها لە بەر ئەوەی زۆر جۆری تر نەبوون کە لە نێوانیاندا هەڵبژێرین. زۆر گرنکە لە سیستەمێکی دەستنیشانکراوەی چاندنی هێڵەییدا بزانرێت کام درەختی زۆر بەکەڵکەاتوو یان دەوەن توانای بەرهەمهێنانی یەکینەی بایۆجییان هەیە و ڕێژەیەکی باشی نیتروجینیان تێدایە.

دەکرێت درخت و دەوەن بۆ باشترکردنی پێکهاتە و بەرزکردنەوەی ئەندازەی کەرەستەی ئورگانیک لە خاکدا بەکاربهێنرێن. گرنگترین شێواز بۆ جێبەجێکردنی هەڵبژاردنی ئەو جۆرانەیە کە توانای بەرهەمهێنانی بەرزی یەکینەی بیۆجییان هەیە کە پاشان دەکرێت ببردرێن و لە خاکەکەدا بەکاربهێنرێن. هەتا ڕەگەکانیش ڕۆڵێکی گرنکیان هەیە بۆ ئەو مەبەستە.

ئاواتەخوازم ئەم کارەم هاوکارێک بێت بۆ ئەو جۆتیارانەی دەیانەوێت چاندنی خۆڕاگر بکەن و پیتی خاکەکەیان باشتر بکەن هاوکات هەمەجووری بایۆجی زیادبکەن. هیوایەکی تریشم ئەوەیە گفتوگۆیەکی خۆڕاگرانە سەبارەت چاندن لە تاکە کولتوورێکدا دەستپێبکرێت و چۆن دەتوانرێت لەوە نەجاتمان بێت، بە بەکارهێنانی بەروبوومی زۆر بەکەڵکەاتوو. هیواموایە ئەم داڕێشتنەم سوودێکی بۆ خەڵکی کورد هەبێت و ڕامانیان بداتێ بۆ کاری باش بە هەمان شێوەی ئەو خۆشەویستیەی کوردەکان لەم گەشتەدا بە منیاندا .

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1. Introduction

A couple of months ago I hardly knew anything about what is now known to me as agroforestry. My interest in growing crops and trees with minimum negative impact on the environment has always been my ambition, and still I had not heard about this way of combining trees, shrubs and annual crops together. Kalida Mohammed, a fellow student at SLU, is born and raised in south of Kurdistan. She sent an e-mail explaining that she wanted to collaborate with other students from SLU – in Kurdistan. She wanted to make a difference in the way people look upon nature and our place as human beings in it, and so did I. My mind pretty quickly settled around the idea that my goal was to do my thesis about new ways of producing food, and growing species that could be used not only for one purpose. Agriculture and forestry can be combined into agroforestry to get the maximum benefits from these two systems. When discussing sustainable agriculture with Helena Karlén and Kalida Mohammed, agroforestry first appeared to me.

Compared to crops growing as monocultures "*agroforestry is a deliberate integration of woody components with agricultural and pastoral operations on the same piece of land either in a spatial or temporal sequence in such a way that both ecological and economic interactions occur between them*" (ICRAF).What separates monoculture and agroforestry I asked myself? I soon realized that agroforestry is not just one way of growing – there are many different designs that could be applied depending on what the goal of the system is. I also wondered what can be improved by growing in an agroforestry system, and in conversations with Kalida I learned that nutrients were lower in the end of each season when growing in monoculture. We thereby had an idea that annual crops grown in monoculture created an unbalanced composition of nutrition in the soil and decreased the organic soil structure below ground.

Due to temperatures up to 47 ^{o}C (117 ^{o}F) in the southern Kurdistan during summer, in combination with low amounts of rain (June has in general one day of rain, where July, August and September gets no rain at all) causes problem with drought (Schnepf 2003). Another problem that has occurred is declining chemical and physical soil properties due to absence of crop rotation (Schnepf 2003). Yields are therefore generally low (Schnepf 2003).

Why monoculture instead of polyculture, in this case agroforestry, is used in such a great extent is because of a higher income that the farmers will earn if specializing (Hislop and

Claridge 2000). The perceived economic benefit is one of the keys to achieve farmers to use trees in their fallow, but attitude and knowledge towards agroforestry also plays an important role to get the farmers to realize the benefits – both economically and environmentally (Hislop and Claridge 2000).

I travelled to Kurdistan in between January 2012-March 2012, because I wanted to study the situation up close to be able to get a more clear view of the situation. At one of my excursions near Kalar I observed an area that was astonishing green and lush. The farmer that produced crops and trees at the site stated that "I now know the secret behind the success Iran is starting to get in agriculture – it is called agroforestry." This quote was dropped from him before he knew what my intention with my visit in Kurdistan was, and naturally this got me intrigued.

I lived in the small town Kalar in Germiyan municipality (seen in appendix A). This town is situated in the south of Kurdistan, northern part of Iraq, close to the border of Iran. Germiyan means hot spot and gives a clear hint about the climate in this area where the temperature can peak at 47 ^{o}C (117 ^{o}F) during summer. The soil at the field consists of clay which creates a hard crust when dried out. This was another reason that intrigued me to investigate whether the soil could be loosened up by adding more organic matter and grow species with deeper root system.

Kalida prepared me that due to the war it is not unusual that people lack knowledge and education about sustainable agriculture. To be able to explain agroforestry to interested people in Kurdistan, I realized that a demonstration site for this new type of growing system could be helpful. The field would also help *me* to understand and realize how complex it can be to grow woody plants in combination with annual crops. Due to the arid climate there were not many trees growing in the area which could improve the soil organic matter. If annual crops are grown intensely as monocultures for many years and very little organic matter is returned to the soil - how will the future for agriculture in Kurdistan be? My intention was to narrow it down and focus on how alley cropping can be used to prevent depletion of the soil: "In what ways can multifunctional trees and shrubs improve soil organic matter and soil structure?"

2. Material and method

Focus has been on searching facts about soil organic matter and agroforestry techniques in databases such as *Web of Knowledge*, *International Center for Research in Agroforestry* (ICRAF) and International *Center for Agricultural Research in Dry Areas* (ICARDA). ICRAF has especially been useful when searching for the appropriate crops to the case.

To further narrow it down, alley cropping as well as soil organic matter and soil structure were used as keywords when finding information. Finding relevant sources has been a challenge as there are more written about agroforestry in tropical climate than in temperate, arid, climate which is relevant for the chosen site.

Among books, *Ecological Basis of Agroforestry* written by Rani Batish *et al.* (2008) has to be pointed out. It is based on many trustworthy sources. Looking for general and basic information *An Introduction to Agroforestry* written by Nair (1993) is recommended.

Kalar

Latitude:34.6352608°
Longitude:45.320491°

Kalar is located in the southeast of Kurdistan, close to the border of Iran.
Kalar city has high (sometimes 47 ^{o}C/117 ^{o}F) temperatures during summer with little or no rain (Schnepf 2003). The soil is heavy clay which creates a hard crust when dried out due to the low amount of organic matter (figure 1).

Today the chosen spot in Kalar is used for research of agricultural crops to find out which species are the best suitable for dry conditions. Machinery such as tractors are being used for preparation, but irrigation canals are dug by hand.

Germiyan Administration Supervisor Salahadin Muhammed Faraj, and the Chief of Kalar municipality Jwad Wadi Saeed were important people for the project due to their immense net of social contacts. It was through them I got in touch with Adbul Karim Mohammed who is in charge of an agricultural research station. Abdul Karim Mohammed, gave me (besides land) coaching whenever it was needed. He possessed knowledge about which and how species will grow, and tried his best to share it in English.

Figure 1. The hard crust preventing the seeds from growing properly.
Photo: Magnus Johansson.

The area around Kalar is named Germiyan which means "hot spot" in Kurdish and thereby gives a hint about the climate and the difficulty to grow plants that demand a certain amount of water.

The material such as shovels, plants and land was given or borrowed to me from people interested in the project. To be able to receive all the necessary material an interpreter followed me for the first week to make sure the purpose with the stay got through in a correct way.

3. Agriculture in Iraq

The surface in Iraq cultivated (2002) is 9.5 million hectares in a total of 43.7 million hectares (Schnepf 2003). Within the total amount of hectares almost half are small size farms which only cultivate fodder to the goats and sheep of the farm. 340.000 hectares of the total hectares tree-crops such as figs, olives, grapes and dates are grown upon (Schnepf 2003). 2.75 million hectares wheat and 715.000 hectares of barely is produced in Iraq, and the remaining arable land in the valleys of Euphrates and Tigris are irrigated (FAOSTAT 2007).
West Asia, Kurdistan included, is a part of non-tropical dry lands such as North Africa, parts of Africa and Central Asia. These areas are already characterized by numerous stresses that include degradation of land, severe droughts and sometimes starvation (Thomas *et al.* 2007).

A factor keeping agriculture at a low state has been the war between Iraq-Iran, which diverted labor and other important resources away from agriculture (Schnepf 2003). The state in 2003s Kurdistan is that it still suffers from the legacy of inaccessible machinery, pesticides, fertilizers and mismanagement (Schnepf 2003).

The main problem in southern Kurdistan is drought, and salinity in the south of Iraq (ICARDA). Another problem that has occurred in the soil is a declining in both chemical and physical properties due to absence of crop rotation. Soil compaction is another increasing

problem together with erosion deriving from monoculture. Yields are therefore generally low (ICARDA).

The drought and the lack of crop rotation in combination with political instability and the recent war have made a major impact at the agricultural production and the knowledge support system (Abi-Ghanem 2009). *The United States of Agriculture* (USDA) founded a consortium of five universities in the USA to offer training to agricultural extension workers from Iraq. This is called The *Iraq Agricultural Extension Revitalizing Program* (IAER), which will promote cooperation between agricultural colleges in Iraq with their governmental agricultural agencies. The demand and need for technology, training, necessary equipment, fertilizers and seeds is immense. To reverse the chemical and physical damage to Iraq's soil, further training about utilizing on-farm recourses is needed (Abi-Ghanem 2009).

4. Soil organic matter

Degradation of land and decreasing soil fertility is a threat to agricultural productivity. Using synthetic fertilizers to increase lost nutrition has been done in many systems in agriculture for years which is not sustainable (Young 1997; Rao *et al.* 1998: Giller 2001; Thevathasan and Gordon 2004; Jama *et al.* 2006b). When speaking of soil organic matter it refers to all organic materials present in the soil. The majority of organic matter has its origin in plants. Soil organic matter consists of entirely decomposed organic matter, humus or plant and microbial remains in various stages of decomposition, called litter (Nair 1993). The organic matter in the soil is essential for water management, terrestrial environment, gas production and nutrition management (Granstedt 2003). Growing plants in a monoculture decreases the organic matter in the soil especially if the entire plant is being taken away when harvesting (Ögren 2003). Using a plow adds nitrogen into the soil and initiates aerobe processes where organisms consume organic matter to survive. By watering the crops the mineralization stays at a high level, and adding that with the aerobe processes the source of organic matter will decrease. When organic matter is added and the organisms thrive, the organic soil structure gets improved. This occurs because of the organisms releasing mucusthreads that stabilizes the aggregates in the soil (Ögren 2003). Humus content gets decreased if not adding organic matter, and lowering the humus content means lowering the number of organisms living in the soil. The organisms are needed to loosen up the soil structure and make it easier for roots to penetrate and find nutrition in the soil. Worms for example increases the available nutrition for plants when digesting the organic matter (Ögren 2003). Without the organic matter the

nutrition in the soil would be less available for the plants, and therefore increase the risk of malnutrition (Ögren 2003).

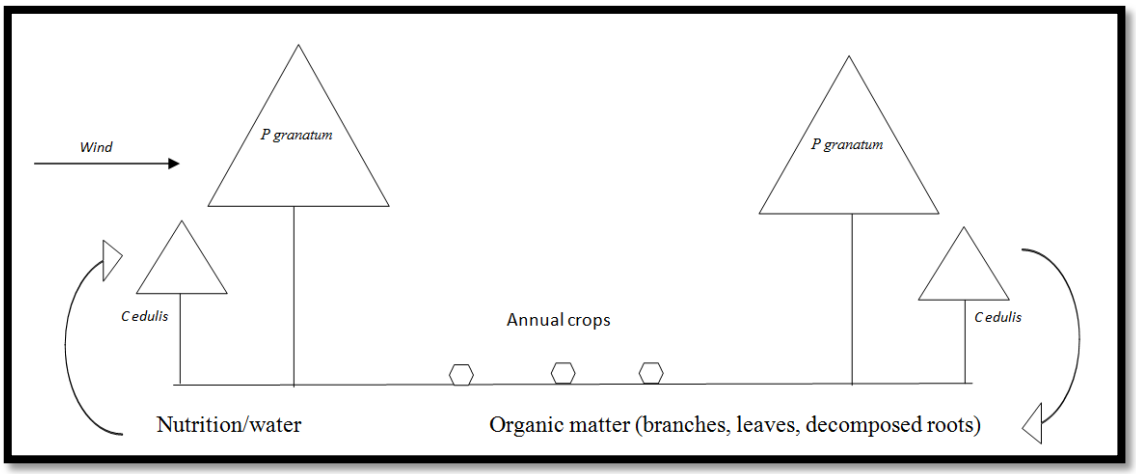

Figure 2. By adding organic matter such as branches and leaves it is possible to increase the available coal, phosphorus and nitrogen in the soil which can lead to higher fertility = more vigorous plants.

Mull consists of dead plants, more or less decomposed, which is a part of soil organic matter (Granstedt 2003). By adding pruned matter to the soil it will decompose - branches in a slower rate than herbaceous plants. When having a 3 % share of mull in the top soil it contributes with 60 ton organic carbon (C), 5 ton nitrogen (N) and 1 ton of phosphorus (P). These are all crucial substances plants need for their growth (Granstedt 2003).

The addition of organic matter is crucial to improve the soil fertility and also increase the water-holding capacity, which is important in dry areas (Tubeileh *et al.* 2004). Adding plant residues (figure 2) in agricultural soils is an important way to improve and sustain soil organic matter and by that also increase the biological activity, nutrient availability, and improve physical properties (Palm *et al.* 2001).

Constant leaf-fall allows uninterrupted nutrient circulation and builds organic matter (Rani Batish *et al.* 2008). The improvement of soil fertility is dependent on soil type, climatic conditions in the area, and quantity and quality of the pruning and tree litter added (Rani Batish *et al.* 2008). Woody species or crops chosen in a system affect the amount of organic matter and mull being brought back to the soil (Granstedt 2003). A plant with a deep root system can leave organic matter at a deeper level due to the penetration. Plants next year in fallow or nearby have shown benefit from a more loosened soil by getting a bigger root

biomass. This will lead to increased opportunities for the plants to catch essential resources such as water and nutrition (Granstedt 2003).

Studies both in Germany and Sweden have showed a higher amount of organic matter in the top soil when growing biodynamic and organically (Granstedt 2003). Just as organic systems can increase organic matter, agroforestry also possesses the ability to increase organic matter and improve soil structure (Breman and Kessler 1997).

5. Definition of agroforestry

The definition of Agroforestry is not always clear to us, but two definitions exist that separate them from other ways of cultivating land, hence: (Nair 1993):

- To grow woody perennials together with agricultural crops and sometimes together with animals. One way is by having the plants in a mixture or in an organized pattern.
- A positive or negative ecological or economical interaction between the different components must exist. This interaction should be between the non-woody and woody material.

The World Bank published a report in 2004 that stated that 1.2 billion people are practicing agroforestry (World Bank 2004). Agroforestry practices are used all over the world but are more common in the tropics. 75% of the farms using agroforestry systems are located in developing countries and managed with traditional means with most often of only a few hectares of land. They rely on a labor-intensive production method with low-energy input. These farmers have used agroforestry practices for centuries because of the need of fodder, fuel, wood and food for themselves (World Bank 2004). To find out on what scale trees, when mixed with agricultural crops, compete for nutrition and other crucial resources several investigations were carried out (Schroth and Lehmann 1995 & Ong *et al.* 1999). The investigations focused on finding non-competitive tree species in order to find out the effect of biomass application. Many of the farmers in the tropical countries are dependent on the annual crops for their survival, but are growing the trees for financial income (Rani Batish *et al.* 2008).

Almost all agroforestry systems have to be monitored for a long period of time (Rao and Coe 1991). The time is longer than annual crop systems, because trees take years to grow and

show their full potential – especially on degraded land (Montagnini *et al.* 2006). There are many different effects possible to achieve with agroforestry (US Department of Agriculture 1996). Among others, and if properly arranged, it can lead to a greater protection of forage and crops, but also contribute with additional products to the farm such as timber, fodder and fruits (US Department of Agriculture 1996). Agroforestry consists of different practices and depending on what problems the land posses the farmers use different techniques and practices (US Department of Agriculture 1996). Integrating trees in agriculture may lead to a higher level of soil fertility, reduce or prevent erosion, improve water quality and enhance biodiversity (Jose 2009).

In the 1990s, evidence came through which supported the belief that agroforestry is of great value especially for farmers' potential to improve the status of the soil organic matter (Breman and Kessler 1997). Agroforestry was shown to improve both quality and quantity of the soil, which gave a potential of intensifying agriculture (Breman and Kessler 1997). The awakening of agroforestry was to be anticipated because of the increasing population and deforestation, but also because of soil degradation and to conserve biodiversity (Rani Batish *et al.* 2008). Agroforestry could be the solution to create sustainable land-use systems and thereby achieve economical, social and environmental benefits (Rani Batish *et al.* 2008).

Besides the definitions there are three attributes that, theoretically, all agroforestry systems possess which are (Nair 1989):

1. *Productivity*: By increased output of tree products, increased labor efficiency, improved yields of associated crops and reduction of cropping system inputs, agroforestry can lead to higher productivity in many different ways. A higher, or maintained, production is the goal of many agroforestry systems as well as a higher productivity of the land.
2. *Sustainability:* Agroforestry can achieve and maintain conservation and fertility goals by conserving the level of production. This is achieved mainly by the effects of woody perennial on soil.
3. *Adoptability*: In this sentence the word stands for "accept". Because the techniques of agroforestry is old and the name agroforestry is a new word for something that has been done for a long period of time, means that these techniques many times already have been accepted by the farming community. However, it is of great importance that if these practices are introduced in to a new area, they should be in line with the local farming practices (Nair 1989).

Every agroforestry practice is more complex - ecologically and economically – than monoculture. It holds interactions among components which is suited to human needs and especially environments (UMCA).

Agroforestry faces several challenges such as competition between trees and crops for nutrition, trees acting as habitat for harmful diseases but also allopathic effects on crops. Agroforestry can only give positive results if the positive interactions are greater than the negative ones (Rani Batish *et al.* 2008).

6. Categories of agroforestry systems

There are five recognized agroforestry practices, which are (UMCA):

- Alley Cropping
- Riparian Forest Buffers
- Windbreaks
- Silvopasture
- Forest Farming

6.1 Alley cropping

The design of alley cropping consists of trees or shrubs grown in corridors (figure 2) or rows with alleys of agronomic crops or fodder in between (USDA 1996). The plants are places with an interval that fulfils the purpose which could be to hinder troublesome winds (USDA 1996). Winds can in some cases be more important to prevent than to try increase the yield (Brandle and Kort 1991). The main purposes of alley cropping are (USDA 1996):

1) Produce tree or wood products in addition to agronomic crops or forage.
2) Improve forage or crop quantity and quality by enhancing microclimatic conditions.
3) Improve recycling and utilization of soil nutrients for forage or crop use.
4) Decrease surplus subsurface water or control water table depths.
5) Providing favorable habitat for animals beneficial to the chosen plants (USDA 1996). To increase soil fertility, biomass and mulch is added to the soil, and trees are pruned regularly (Rani Batish *et al.* 2008).

Trees in alley-cropping arrangements have the opportunity to influence the spread of diseases, weeds and insect pests (Rani Batish *et al.* 2008). In Kenya studies have shown 42% – 98% reduction in weed biomass in alley cropping. In Costa Rica two other studies showed a 52% and 28% reduction in weed biomass – also in alley cropping. These results show us a quite a

considerable difference between place and species used in the system (Rani Batish *et al.* 2008).

Improve crop production, diversify farm income and provide conservation and protection benefits to crops are some of the advantages in alley cropping (Center for Agroforestry 2009). The trees selected for alley cropping might be trees such as nut trees or trees desirable for wood products, which are valuable hardwood (Center for Agroforestry 2009). Despite many positive effects coming from alley cropping, negative effects may occur as well (Rani Batish *et al.* 2008). If incorporating them into an existing agricultural crop, competition for water, light and nutrients could appear. If the trees and shrubs in the alleys use the essential growth resources, it can do so at the expense of the crop growing in between them. This could lead to a decrease in yield.

Can the positive effects compete with the negative ones? A farm with tea plants showed that the root system of tea plants stayed in the upper 30-45 cm (12-18 inches) of the soil (Rani Batish *et al.* 2008). Species in this type alley cropping should therefore have a root system that reaches below 30-45 cm (12-18 inches) and therefore not compete for water and nutrients. It also transfers the nutrients not available for the tea plants to biomass, which later can be pruned and added to the soil where the tea can reach the nutrients. This also contributes with soil organic matter and prevents important resources to get lost (Rani Batish *et al.* 2008).

It has been well documented that agroforestry has a positive effect on the soil sustainability and productivity (Jose 2009). Nitrogen (N)-fixing trees are fairly common in tropical agroforestry systems, but trees not able to fix nitrogen can also enhance soil chemical, biological and physical properties by adding considerable below and above ground organic matter, and releasing and recycling nutrients (Jose 2009). One example is *Alnus rubra* fixating nitrogen in a maize alley cropping system in Oregon, USA, showed that 32-58% of the nitrogen was obtained from the nitrogen fixed by *Alnus rubra*. The study also showed that the nitrogen transfer increased when decreasing the distance between crops and trees (Jose 2009).

The interaction between trees and crops are of great importance to be able to estimate or calculate the economic and ecological sustainability (Rani Batish *et al.* 2008). In one field of *Vigna radiate* (mung bean) growing between alleys of trees, the yield decreased closer to the

trees and increased by the distance (Wiersum 1991). The dry weight and leaf area were at the same time lesser compared to those more far away from the trees (Wiersum 1991).

Many cases have been carried out, especially in the tropics (Rani Batish *et al.* 2008). One thing all cases had in common was the competition between the species for necessary resources. When planning and designing the agroforestry system, it is of great importance to encounter the competition among them and choose species that will not compete too much with each other. However, if properly designed it can increase yield, reduce soil erosion, and surface runoff. By adding pruning as mulch, which has seen to be very profitable, the field is one step closer to increase the soil fertility. The case also showed that alley cropping increased the soil organic matter and recycling the nutrients compared to crops grown as monocultures (Rani Batish *et al.* 2008).

7. Problems to be solved

7.1 Improve soil organic matter and soil structure

Maintaining and increasing soil organic matter comes from provision of the litter and root residues (Nair 1993). Woody perennials give different organic matter when it comes to rate and their time of addition. When harvesting herbaceous plants, for example, there are usually specific peaks of organic material accumulation to the soil, compared to the woody perennials, which give a somewhat steady addition of organic material. The woody organic material such as branches decomposes in a slower rate than herbaceous crops, and therefore contributes more to the organic soil structure in the longer run. Most of the quality of pruning material affects the rate of which the nearby crop can take advantage of N released by the pruning and litter (Mulongoy *et al.* 1993). Litter and pruning that decomposes slowly gives higher yield to the agricultural crop if added early, compared when added later in season (Mulongoy *et al.* 1993).

In one study agroforestry systems gave improved soil aggregate stability and nitrogen, carbon, and enzyme activity increased when compared to annual crops (Jose 2009). Trees differ in their growth of roots and therefore it is important to remember that not all tree species are suitable to act as an erosion retainer and contribute with mulch (Rani Batish *et al.* 2008). Hence the importance of finding a range of species that could be used in interaction with different crops and other lignified species (Rani Batish *et al.* 2008). Trees generally have a

root system that penetrates the soil to a deeper level compared to annual crops (Rani Batish *et al.* 2008). The trees therefore have more access to the water deeper down in to the soil. Many of the woody perennials, which are used in alley cropping, are high in nitrogen and when pruned and applied to the soil it will result in an increased level of available nitrogen for crops nearby (Nair 1993). In one study *Senna spectabilis* was the species who added the highest amount of nitrogen (N) to the soil (De Costa *et al.* 2005). This even though the leaf did not contain the highest amount of N, but since *S spectabilis* produces a higher amount of biomass it compensated the lower levels of N (De Costa *et al.* 2005). This is one of the reasons to embrace species high in nitrogen and with a high biomass production in alley cropping (Nair 1993). When pruning from trees in alley cropping were added to the soil in a tea plantation, measurements showed that several of the species supplied nearly enough with the recommended amount of the major nutrients (Rani Batish *et al.* 2008). Another species, *Acacia*, is expected to be especially efficient to recycle nutrients due to its re-growth ability after pruning (Mafongoya and Dzowela 1999). This was shown in a field with maize, where the pruning was added as mulch or green manure.

Trees in agroforestry systems have shown to increase nutrient pool, activities of enzymes and organic biomass (Rani Batish *et al.* 2008). Trees can improve soil biological and physicochemical properties by these general mechanisms:

- Release of nutrient from tree litter and pruning
- Nitrogen input through biological nitrogen fixation
- Phosphorus input through mycorrhizal associations
- Reduced soil erosion and nutrient leaching
- Nutrient capture from the subsoil through deep-rooted trees
- Redistribution of nutrients through lateral roots of some trees

Windbreaks, for example, in agroforestry systems are effective in stopping sediments, nutrients, and fertilizer from running of the surface (Rani Batish *et al.* 2008). The row with trees and bushes creates a barrier to prevent the soil from eroding, particular in fields lying on a slope. By choosing species that have a deep root system, the system can retain the nutrients from leaching and creates a more closed nutrient-cycle (Rani Batish *et al.* 2008).

Alley cropping can increase yield if properly designed, but decrease yield if poorly designed such as too great competition between crops and trees. The damaging erosion caused by wind

and water can be somewhat prevented by planting trees that creates a canopy, which makes the damage by wind and water erosion not as severe as without trees. Physical barriers like stems, roots and litter fall also helps to protect the soil from surface runoff. Speaking of organic matter - agroforestry systems can add profound amounts of organic matter which helps protect the soil from erosion and at the same time improve soil physical properties. A recent study showed that with the use of *Alnus rubra* and *maize* in alley-cropping the organic matter increased with 4-7% (Rani Batish *et al.* 2008). When abundant organic matter is present, the soil compaction reduces and leads to increased porosity and infiltration (Rani Batish *et al.* 2008). In addition to the positive effects of increased soil, organic matter, and litter fall from crops and trees, the N-supply in the soil increases. One report showed that when pruning the trees in semi-arid areas heavily, there were no apparent competition for water, but this could also be due to the shedding of roots.

In a field where tea was grown as the main crop, alley cropping decreased the nutrient pool, but at the same time showing optimistic results for soil organic matter in the long run (Rani Batish *et al.* 2008). The organic matter turned out differently depending on the chosen species and between mulching treatments. This result probably occurred because of different amounts of pruning were added from different species in the alleys, and that the size of the root system differed between them (Rani Batish *et al.* 2008). When a tree is pruned above ground the competition for nutrients and water in the soil could increase due to a higher speed of root mass production (van Noordwijk and Purnomosidhi 1995). In two (out of six) combinations of mung bean grown together with different tropical trees in alley cropping, physical and chemical properties were improved to a level that outweighed the negative effects coming from the competition between resources such as water and nutrition (Kang *et al.* 1990). The organic matter derived from pruning, added as mulch, and could be an explanation of the positive effects (Kang *et al.* 1990). Independent on what species of trees used, the soil organic matter increased when mulching (Rani Batish *et al.* 2008). The outcome of these trials showed that some of the key soil physical properties related to long-time fertility, increased when tree hedges were incorporated. When mulching yield increase which means that a higher amount of nitrogen (N) is removed. This has to be replaced. To be able to choose the appropriate crop is not just a matter of choosing the right species or crops according to Rani Batish *et al.* (2008) but also to use mulching. Another aspect to understand is the competition that occurs below and above the ground (van Noordwijk and Purnomosidhi 1995). Agroforestry practices affect the microclimate around the crops which includes shading,

reduced air and soil temperatures, increased relative humidity, and decreased wind speed (Rani Batish *et al.* 2008).

7.2 Competition

Shade from trees in agroforestry mostly has a negative effect on crop productivity (Rani Batish *et al.* 2008). As mentioned earlier, this may differ depending on the combinations of soil type, crop and tree species being used. However, shading also can have a positive effect during the right conditions and in combination with appropriate crops. Shaded intercrops can result in positive effects, for example increase forage yield, weed density and increase maize yield (Rani Batish *et al.* 2008).
Shade from trees plays an important role in reducing pests in agroforestry systems, such as alley cropping. The trees give shade, which lowers temperature and therefore the microclimate (Rani Batish *et al.* 2008). Shading plays an important role especially in dry seasons. Due to the ability to reduce soil temperature near the hedgerows the evaporation may decrease (De Costa *et al.* 2000).

Even though shading gives positive effects in some ways, it may affect the plants negatively (Livesley 2002). Maize grown in between two alleys, gave less yield close to the hedgerows. There was an obvious competition for valuable resources such as nutrition, but also for light and water (Livesley 2002).

Competition between trees and crops for limited resources could increase the stress level in plants (Rani Batish *et al.* 2008). One result that was equal for all the cases was that no matter how the field was designed, there was always a competition between the species for necessary resources (Rani Batish *et al.* 2008). It is therefore important to design a system and choose species, which not are very competitive (Rani Batish *et al.* 2008).

In arid areas competition for nutrients and water is the biggest issue and this could easily affect the resistance towards pests and diseases among growth and yield (Rani Batish *et al.* 2008). Trees have also a higher biomass of fine roots than crops (Rani Batish *et al.* 2008). In some cases crops and trees may have different soil water pools, but many times they are competing for the same water and when this happens most often the tree roots have an advantage in water uptake due to higher root biomass. Competition between the roots of crops and trees may occur, this however, does not have to be all bad (Eastham *et al.* 1990). Sometimes competition can lead to that the roots of the trees reach further down in the soil

and use water and nutrients that would otherwise not benefit the vegetation. Therefore the plants could become more resistant to drought (Eastham *et al.* 1990).

Intervals between rows should be wide enough to permit sufficient light to crops in the alleys (USDA 1996). However, studies have shown that alley cropping has the ability to increase or sustain soil fertility and yields – especially on heavier soils (Mafongoya and Dzowela 1999).

When soil erosion and surface runoff was measured during one year, there was a much lower amount of soil erosion and water runoff in alley cropping, when compared to a surface with annual crops in monoculture (Wiersum 1991). The erosion was worst in the beginning of the crop period as the plants did not shelter the loose soil from heavy rainfall. The surface runoff lead to a greater loss off soil nutrients in the fields not being alley cropped.

8. Case study

One field was established according to agroforestry practices, alley cropping to be precise, during the project in Kurdistan. First there will be a presentation of how this can be done in theory followed by how to go through with this in reality.

8.1 In theory

When designing a system based on alley cropping, it is important to use plants that matches the goal for the production (Kho 2000a. 2000b). If the goal is to increase soil organic matter and improve the soil structure the design should be based on that decision.

Suitable trees and shrubs are according to USDA, 1996:

- Adapted to the climate and the soil at the chosen planting size.
- Produces products suitable for the purpose, such as wood, fodder or fruit.
- Resistant to pests and pesticides.
- Tolerant of sediment deposition and pollutant-laden runoff.
- Will have branches and stems strong enough not to break from ice, snow and winds (USDA 1996).

Some trees can be excluded from improving soil organic matter because of negative impacts on the intended goals (Rani Batish *et al*. 2008). Agroforestry trees in semi-arid and arid areas can be managed so that productivity and water use lies at an optimum level. This can be done by *not* using evergreen trees such as *Eucalyptus* that need large amounts of water during summer. Besides *Eucalyptus, F albida* should be avoided in arid areas, because it produces

branches and leaves during dry season and therefore demand more water (Rani Batish *et al.* 2008). *Eucalyptus* is a very common cultivated tree throughout this region in Kurdistan (Rani Batish et al 2008). It grows fast and is evergreen. In addition, it is easy to handle and requires less care than many other trees. *Eucalyptus* uses a lot of water to maintain its green branches all year around and because of the speed it is growing. *Eucalyptus* is not a well suited suggestion also due to its allelopathic effects. Allelopathic plants are those which affect other plants in a negative way by emitting substances. *Populus deltoides* is another tree with allelopathic substances that could decrease yield significantly if being grown near crops and trees in the farm (Rani Batish *et al.* 2008). The major part of the trees chosen in general in alley cropping are fast growing and leguminous, which can be pruned regularly and therefore contribute to building up the soil structure and add mulch (Rani Batish *et al.* 2008).

To increase soil organic matter and improve the soil structure species that give accumulation of both active and slow fractions of organic matter are the most ideal (Rani Batish *et al.* 2008). Species being pruned and not being evergreen are trees that contribute with slow (pruned branches) and fast (leaves) fractions of organic matter. If the proper species are chosen for this task it could activate soil biology, and elevate the nutrient status of soils (Rani Batish *et al.* 2008).

To summarize the cases and studies that have been carried out in recent years, it is possible to say that the system have potential to both fail and succeed depending on the design and what plants or crops involved (Rani Batish *et al.* 2008). This in combination with how the field is planned and maintained: too close distance could increase risk of root competition, but too big distance could make the improved soil structure not getting benefitted by the annual crops.

8.2 In practice

The study took place between 21st of January – 6th of March. The weather conditions at time were somewhat cold and rainy. The winter at the chosen spot stretches from December until March, and daytime temperatures in Kalar varied from 2 ^{o}C – 19 ^{o}C during these two months. The highest amount of rainfall comes during winter with an average rainfall in February of 51 mm (World Weather Online 2011). Due to the small amounts of rain and many cold nights there were no weed, and during the whole study no problems with weed occurred. The soil was clay which created a hard crust when dried out after one day of raining.

Many farmers in countries worldwide want maximum amount of sun and establish their field in north-south direction, but since the sun is almost too intense the field was established due to other factors. Besides the main goal to plant species that would improve soil structure and increase soil organic matter the idea of the shrubs and trees was to shelter the annual crops in between from wind. The most troublesome and strongest wind came from the north why the field was established in an east-west direction.

The field was plowed and harrowed to loosen up the soil and create the best possible conditions before the plants/seeds were put in the ground. The field measured 20 m x 20 m (60 x 60 feet). The field was divided into three areas, where two of the areas would be dedicated to grow woody plants. One of the areas, the center one, would be dedicated for vegetables.

Irrigation systems are widely used in Iraq, as well as in southern Kurdistan. These are made by digging up "walls" at the sides and form a canal where the plants will grow. A rake was used to get rid of big lumps of soil and stones to prepare for the seeds. There were practically no rocks which made it somewhat easy to prepare for the seeds.

Each parcel was divided into three rows and marked with holes for seeds of the annual crops. Seeds were sown approximately 3 cm (1.25 inches) deep and in every 20 cm (8 inches). Between the rows, there was a distance of approximately 50 cm (20 inches). Three rows of *Solanum melongena*, aubergine, were put into the ground. Several days of rain followed, which made it impossible to continue the work in the field. The remaining two rows were prepared for the seeds. In the first row *Cicer arietinum*, chick pea, was sowed and in the second one *Capsicum annuum*, bell pepper. These parcels were sown with a row space of 40 cm (16 inches) and a space between the plants of 15 cm (6 inches).

The plants were watered by using the dug irrigation system. Over all it went very well, but some minor changes had to be made. One problem was that one end of the field was too steep for the water to enter the area. Another irrigation canal had to be dug around to allow the water in from the other side. The second adjustment that had to be done was to make the walls in the irrigation system slightly more powerful, because the water eroded away some of them (figure 3). The greatest learning when establishing the crops and woody plants was that the most important thing is to be well aware of the specific below- and aboveground interactions of all species chosen. If not having an accurate knowledge about the woody plants chosen the

aimed purpose might not be achieved. Trees and shrubs might even have to be taken away due to the miscalculation and carelessness about the complex interactions between the species. These factors can cause great distress for a farm of any proportion.

Figure 3. Using the irrigation system for the first time. Photo: Victoria Andersson.

Many hours were spent digging the irrigation system and a thought whether how that could be done in an agroforestry farm of bigger proportions came up. A lot of the work was done by hand, except when the field was harrowed and plowed. So even though alley cropping, about design speaking, has the ability to be harvested and established with machines, the resources and knowledge might not be sufficient yet.

When the irrigation system was at place, the local garden centers were visited to localize the trees, shrubs, and crops needed in the field. There were no quality certifications of any kind, so the plants were examined as carefully as possible to get the most vigorous ones. There were not many species to choose from. Most gardens centers had *Musa* ssp (banana), *M nigra* (mulberry), *Oleaus europeus* (olive) and *P granatum* (pomegranate) in their basic selection.

To find an appropriate shrub which could be beneficial in several different ways was difficult due to the lack of species in the garden centers. *Carissa edulis* was the only shrub found in this area which fulfilled the basic agroforestry demands. *Punicum granatum* was the tree which seemed the most suitable for the project. The lignified species such as *P granatum* and *C edulis* have a greater impact at the soil structure because of their deep root system and biomass production. The farmer needs to decide if the multifunctional woody plants are more important to focus on than the annual crop, which was the case in this thesis.

In this case the different functions of shrubs and trees were more relevant, more precisely, the organic matter and the root impact at the soil that they possess.

The second purpose with the woody plants was to shelter the crops in the middle from troublesome wind (figure 4), *C edulis* was planted in the outer end of the land at each side (see further in figure 2, page 6). Two meters (7 feet) between the plants gave nine plants for each of the two rows. *P granatum* was planted at the inside of *C edulis* with a space between the trees of 3.25 m (11 feet). This resulted in six trees at each side, and a total number of twelve trees when putting the both sides together. *P granatum* was planted somewhat close to each other in order to be able to act better as shelter for the wind.

Figure 4. Planting *C edulis* in outer end to prevent troublesome winds from damaging the crops in the middle.

9. *Punica granatum*

Suitable soil type: Well drained, light, heavy and medium soils.

P granatum is a small tree or a shrub, which grows 5-10 meter (15-30 feet) in height (Orwa *et al.* 2009). It is drought tolerant and suitable for semi-arid and arid climate. It is native to Iran and Afghanistan, but is widely cultivated throughout India and the more arid parts of East Indies, tropical Africa, and South East Asia (Aromatic news 2005).

P granatum is tolerant to soil compaction, seasonal water logging as well as drought (Orwa *et al.* 2009). *P granatum* has a very broad area of use: the fruit is used as food in many ways, where eating the seeds and making juice of them is two ways. 100 ml juice of *P granatum* contains approximately 40 mg vitamins, which make them a good source of vitamins. The branches can be used as firewood and the leaves as fodder for livestock. The wood can be used for making farm implements and is hard and durable. The black ink from root bark is rich in tannins and is used when tanning and dyeing leather (Orwa *et al.* 2009). Parts of the tree can also be used as medicine for a variety of complaints.

Prevent erosion and improve soil organic matter:

Most importantly, the *P granatum* plays a central role in erosion control, where the trees have been planted along rivers to hold the soil back with their long and deep roots (Orwa *et al.* 2009). Leaf litter of this tree decomposes slowly and hence suitable for mulching. It is also a

good tree to use as a wind break, as well as using it as a shade tree (Orwa *et al.* 2009). *P granatum* is used in water purification and can handle slightly saline water and soil (Aromatic News 2005).

10. *Carissa edulis*

Suitable soil type: Tolerates most soils.

Family: Apocynaceae.

Small shrub with thorns which can grow up to 3-5 meter (9-15 feet) (ICRAF). *C edulis* natural habitat is in Arabia, but reaches through tropical Africa. It prefers dry areas, but with some access to water.

Products from *Carissa edulis* is the sweet fruit, which can be eaten ripened or made into jam. Vinegar can be made from the fruit and the roots can be put into soups and stews to add flavor. The root has also been investigated for treating cancer. Leaves of *C edulis* can be used as fodder for animals and the wood makes good firewood. The leaves and roots are also used against malaria and as medicine, such as reliever for tooth ache and other pains.

Prevent erosion and improve soil organic matter:

Carissa edulis answers well with pruning, which supports the idea of using leaves and branches to improve the organic soil matter (ICRAF). It is also suitable to use as a boundary or barrier, which would be suitable in alley cropping against troublesome winds.

11. Discussion

11.1 The role of organic matter.

Organic matter in the soil brings a lot of positive benefits: enables organisms to thrive, increase amount of aggregate and making the soil porosity increase. All this leads to a positive development of the plant – the root system easier reaches nutrition due to the looser soil but the nutrient is also more accessible due to the work of organisms (Granstedt 2003). Roots from trees or shrubs could on the other hand create competition among each other which could decrease the yield and thereby the income for the farmer (Eastham *et al.* 1990).

Multifunctionality is important in this case due to that the main goal is to improve soil organic matter and structure – but how will the farmer gain economically by this? The average farmer

possesses two acres of land and cannot afford to leave land uncultivated. A yield is expected at the same time as the goals should be fulfilled which creates a demand for using species that are multifunctional.

I raised the question:"In what ways will multifunctional trees and shrubs improve soil organic matter and soil structure?" The result shows that in order to achieve this, trees and annual crops that have a deep root system and a high production of biomass should be chosen. If the tree at the same time has a high level of N it gives the best possibility to increase soil structure and improve soil organic matter.

11.2 The selection of plants

To be able to choose the trees, shrubs and crops in alley cropping, one must read and understand the complexity of both below- and above ground circumstances. One of the most important facts to understand is that – when speaking of improving soil structure and organic matter – different species add different amounts of litter to the soil. Different species also affect soil structure differently due to the fact that they have different sized root systems (Jose 2009).

The process of choosing the right crop is to have deep knowledge about how the tree, bush or crop works. How much branches will it produce and will I be able to prune without damaging the tree? How wide and deep will the root system become? Do I need to mulch or not? At what time of the year is the best time to prune the specific plant? Can the branches and leaves be used for something else than to improve soil organic matter with? And what other beneficial qualities does this plant have that could gain animals, plants, soil and humans in the area?

The chosen trees should respond well to pruning and not be evergreen such as *Eucalyptus*. *Eucalyptus* is evergreen and not appropriate due to its immense demand for water even during winter. *Carissa edulis* answers well with pruning and *Punica granatum* contributes with a high biomass production and a deep root system. These two can therefore be considered as suitable to use in alley cropping in a dry area such as Kalar. *Carissa edulis* however has a slightly higher demand for water, which increases the maintenance. If a multifunctional shrub with greater tolerance to drought is found it would be of interest to examine of it will be more appropriate compared to *C edulis.*

Competition In a field where tea was grown as the main crop, hedgerows decreased the nutrient pool, but at the same time showing optimistic results about soil organic matter in the long run (Rani Batish *et al.* 2008). The organic matter turned out differently depending on the chosen species and if mulching was applied or not.

My conclusion of this is therefore that each site where alley cropping is applied has to consist of species which has specifically been chosen for the climate, conditions and soil. The species should have a somewhat high production of biomass since a high production improves soil organic matter in a faster rate compared to a low biomass-producing tree (Rani Batish *et al.* 2008). When pruned biomass such as branches and leaves are added to the soil, it can increase soil organic matter and improve soil structure. The root system of trees and shrubs will loosen up the heavy soil and in the long run develop a soil not as dense as before.

11.3 The future

Profitability is another factor that needs to be recognized in order to optimize production and sustainability in alley cropping. More baseline information about tree spacing, tree crop configuration and their role in the system is needed (Rani Batish *et al.* 2008). Results from studies about alley cropping can be used to educate landowners and farmers about alley cropping and its potential as a multifunctional way to cultivate and to design more sustainable farming systems worldwide (Rani Batish *et al.* 2008).

It is difficult to say whether agroforestry technology would lead to increased yield, profitability, or not depending on the location and plants chosen (Rani Batish *et al.* 2008) To find out whether one combination of woody plants would suit several different sites more research is needed. If it can be settled that one combination of species is suitable for one area, another area with the same problems should be tested with the same combination. Since the chosen species for Kalar has the ability to improve soil structure and organic matter due to their deep root system they could create a soil more suitable for sowing. The hard crust may soften due to the organic matter and therefore be more eligible to grow in, which in the long run could increase yield.

Since the definition of agroforestry is to grow trees and shrubs together with annual crops and sometimes with animals (Nair 1993), the thought of how appropriate the species are for animals must be taken into consideration if animals will be a part of the system. If animals are

included the crops growing will probably partly be fodder. The trees might be chosen due to their ability to provide shelter and shade for the animals but at the same time be able to be pruned to feed the livestock.

Another factor that influences the spreading of agroforestry is, in USA and Australia, that agroforestry equals taking bigger economical risks compared to grow crops as monocultures (Campbell White & Associates and Black 1999). One part in why agroforestry not yet is proven to be an economically profitable system is that almost every case only have been tried out in theory (Dupraz and Newman 1997).

Further research is needed about alley cropping systems in dry areas and especially tree crop interactions between specific species. In many tropical areas the land is still cultivated by using old agroforestry techniques.

When alley cropping is compared to monoculture one of the greatest differences is the multifunctionality that the system possesses. By using several species, and sometimes in combination with livestock, the farmers have a bigger possibility to create a more diversified system that recycles the current resources. Not only positive effects follow with this way of growing. Since the system contains woody plants which take years to reach maturity, it is not a fast way for income or results. Improving soil organic matter and soil structure is a process that demands a long period of time where the demand for manual power is higher compared to growing annual crops in a monoculture.

The sizes of farms in Kurdistan are mostly small, but the interest for expanding the agriculture makes it important to create and develop systems that could be applied when the farmers want to expand their business. Alley cropping was the one out of five possible systems chosen because of the possibility to apply these techniques to a production of larger proportions. The system makes it possible to use machines, such as tractor, plow and harrow in the rows.

The degradation of land in south of Kurdistan has to be dealt with. Increase of the exchange of knowledge between agricultural research centers, universities and farmers will play a major part. There is a great willingness in Kurdistan to reach a higher standard in agriculture but the access to knowledge is lacking - farmers have to be taught how to deal with degrading land. Agroforestry systems could be one way to increase soil organic matter and improve soil structure. Visiting other farms that have been successful in using agroforestry techniques is another way to approach the problem. The field established in Kurdistan has many years to go

before showing any results, but can still act as a platform for exchanging knowledge and form discussions between interested farmers and organizations, farmers and students.

Some obstacles still stand in the way of agroforestry (Rani Batish *et al.* 2008). One of them is that the technique is not very well known throughout the public, which creates space for being misapplied. If the system is considered possible to apply, alley cropping would have a greater chance of being adopted by farmers and winning social acceptability (Rani Batish *et al.* 2008). A crucial strategy for preventing unanticipated and negative outcome is a careful selection of tree and crop species. The woody plants should at least posses the following characteristics: adaption to the soil and climate at the site where planted; production of fruit, wood or fodder suited for the purpose of the plantation; resistance to herbicides and pests; tolerance of sediment deposition and pollutant-laden runoff; and at last resistance towards branch- and stem-breakage from high winds, snow and ice (Rani Batish *et al.* 2008).

To sum it up: it is possible to use multifunctional woody plants to improve soil organic matter and soil structure. To succeed the species should have a high production of biomass, and advantageously a high level of N content in their leaves and therefore add both organic matter and contribute with N (which makes the plants more vigorous). Evergreen species like *Eucalyptus* should not be used in an arid climate such as Kurdistan due to its vast water uptake. *Punica granatum* and *Carissa edulis* is the most suitable for Kalar due to the limits of species to choose from in combination with their multifunctionality and adaption to arid climate.

In the future more studies, hopefully, will be carried out in dry areas such as Kurdistan. When sufficient information about this way of growing exists it will be necessary to see if it is possible to apply at farms of bigger proportions. Therefore increase income and make it more attractive fot large scale-farmers to adapt to this way of producing food and other products. Growing organically was once seen as something like a hobby, and agroforestry seem to have the same status nowadays. Will agroforestry develop and show just as much potential as organic farming do today? There are many questions still to be answered, but by doing more studies which can gain farmers all around the world we are one step closer to increase the knowledge and credibility about something that today is given slim amount of attention. Agroforestry – the future way of sustain soil fertility and improve soil organic matter?

12. Literature

Abi-Ghanem R. 2009. Optimizing biological nitrogen fixation and evaluating Iraqi extension education. Available at: http://www.dissertations.wsu.edu/Dissertations/Summer2009/R_Abi-Ghanem_070909.pdf
Accessed 2012-04-05.

Adary A., Hachum A., Oweis T and Pala M. 2002. Wheat Productivity Under Supplemental Irrigation in Northern Iraq. International Center for Agricultural Research in the Dry Areas (ICARDA). On-Farm Water Husbandry.

Aromatic News. 2004-2005.

Brandle J.R. and Kort J. 1991. WBECON: A windbreak evaluation model. 1. Comparisons of windbreak characteristics. In *Proceedings of Third International Windbreak and Agroforestry Symposium*, 129-131. Ontario, Ridgetown, Canada: Ridgetown College.

Breman H., Kessler J.J. 1997. The potential benefits of agroforestry in the Sahel and other semi-arid regions, *European Journal of Agronomy* 7:25–33.

Campbell White & Associates and Black. A. 1999. *Practical Farm Forestry: Whole Farm Case Studies*. Kingston, ACT: Rural Industries Research and development Corporation.

Center for Agroforestry. 2009. An Integrated Vision for Agroforestry 2009 annual report: *Research, Partnerships & Technology Transfer*. Available at:
http://www.centerforagroforestry.org/pubs/annual09.pdf
Accessed 2012-04-29

De Costa W.A. and Chandrapala J.M. 2000. Environmental interactions between different tree species and mung bean (*Vigna radiata* (*L*.) Wilczek) in hedgerow intercropping systems in Sri Lanka: 2. *Journal of Agronomy and Crop Science*184: 145-152.

De Costa W.A.J.M., Surenthran P and Attanayake K.B. 2005. Tree-crop interactions in hedgerow intercropping with different tree species and tea in Sri Lanka: 1. Production and resource competition. *Agroforestry Systems* 63:199-209.

Dupraz C. and Newman S.M. 1997. Temperate agroforestry: the European way. *Temperate Agroforestry systems*, ed. Gordon A.M. and Newman S.M., 181-236. Wallingford, UK: CAB international.

Eastham J and Rose C.W. 1990. Tree/pasture interactions at a range of tree densities in an agroforestry experiment. I. Rooting patterns. *Australian Journal of Agricultural Research* 41:683-695.

FAOSTAT. 2007. FAOSTAT. Available at http://faostat.fao.org. Accessed 2012-03-12.

Giller K. 2001. *Nitrogen Fixation in Tropical Cropping Systems.* 2nd edition. Wallinford, UK: CAB International.

Google. 2012. Kalar, Iraq. [Online]. Tele Atlas. Available at: http://www.findlatitudeandlongitude.com/?loc=Kalar%2C+Iraq&id=306451 Accessed 2012-05-10

Granstedt A. 2003. Markens egenskaper och markvård i ekologisk grönsaksodling. In: Ascard, J. and Bunnvik, C. (red.) 2008. Ekologisk odling av grönsaker på friland. Kurspärm, Jordbruksverket.

ICRAF. World Agroforestry Centre. A tree species reference and selection guide. *Carissa Edulis*. Available at http://www.worldagroforestrycentre.org/sea/products/afdbases/af/asp/SpeciesInfo.asp?SpID=443. Accessed 2012-04-05

ICRAF. World Agroforestry Centre. A tree species reference and selection guide. *Morus nigra*. Available at http://www.worldagroforestry.org/sea/products/afdbases/af/asp/SpeciesInfo.asp?SpID=1172 Accessed 2012-05-08

International Center for Agricultural Research in the Dry Areas, ICARDA. High-value crops for better nutrition and income. Available at http://www.worldagroforestry.org/treesandmarkets/hvc07_meet/other_materials/ICARDA/Horticulture%20new%20version.pdf.
Accessed 2012-05-08

Jama B., Kwesiga F. and Niang A. 2006b.Agroforestry innovations for soil fertility management in sub-Saharan Africa: prospects and challenges ahead. *World Agroforestry into the Future*, ed. Garrity D., Okono A., Grayson M. and Parrott S., 53-60. Nairobi, Kenya: World Agroforestry Centre.

Jose S. 2009. Agroforestry for ecosystem services and environmental benefits: an overview, 76:1-10.
Kang B.T., Reynolds L. and Atta-Krah A.N., 1990, Alley farming. *Advances in Agronomy* 43:315-359.

Kho R.M. 2000a. A general tree-environment-crop interaction equation for predictive understanding of agroforestry systems. *Agriculture, Ecosystems and Environment* 80:87-100.

Kho R.M. 2000b. On crop production and the balance of available resources. *Agriculture, Ecosystems and Environment* 80: 71-85.

Livesly S.J. Gregory P.J. Buresh R.J. 2002.Competition in tree row agroforestry systems. 2. Distribution, dynamics and uptake of soil inorganic N. *Plant and Soil* 247:177-187.

Mafongoya P.L. and Dzowela B.H. 1999. Biomass production of tree fallow and their residual effects on maize in Zimbabwe. *Agroforestry Systems* 47:139-151.

Montagnini F., Eibl B. and Fernandez R. 2006. Rehabilitation of degraded land in Misiones, Argentina. *Bois et Forêts des Tropiques*. 288:51-65.

Mulongoy K., Ibewono B.E., Oseni O., Kulumba N., Opara-Nadi A.O. and Osobuni O. 1993. Effect of management practices on alley cropped maize on nitrogen derived from prunings on a degraded alfisol in southwestern Nigeria. *Soil Organic Matter Dynamics and Sustainability of Tropical Agriculture*, ed. Mulungoy K. and Merck R., 223-230. Chichester, UK: John Wiley & Sons Ltd.

Nair P.K.R. 1989. Agroforestry Systems in the Tropics. Kluwer Academic Publishers, the Netherlands.

Nair P.K.R 1993. An Inroduction to Agroforestry. Kluwer Academic Publishers, the Netherlands.

Ong, C.K., Deans, J., Wilson, J., Mutua, A.A.H. Khan and E.M. Lawson. 1999. Exploring below ground complementarity in agroforestry using sap flow and root fractal techniques. *Agroforestry Systems* 44:87-103.

Orwa C. Mutua A , Kindt R , Jamnadass R, Simons A. 2009. Agroforestree tree Database: a tree reference and selection guide. *Punica granatum*. Available at: http://www.worldagroforestry.org/treedb2/speciesprofile.php?Spid=18036 Accessed 2012-02-20.

Orwa C., Mutua A., Kindt R., Jamnadass R. and Simons A. 2009. Agroforestree Database: a tree reference and selection guide. *Morus nigra*. Version 4.0. Available at: http://www.worldagroforestry.org/sea/products/afdbases/af/asp/SpeciesInfo.asp?SpID=1172 Accessed 2012-04-14

Palm C.A., Gachengo C.N., Delve R.J., Gadisch and Giller K.E. 2001. Organic inputs for soil fertility management in tropical agroecosystems: application of an organic resource database. *Agriculture, Ecosystems and Environment* 83:27-42.

Rao M.R., Nair P.K.R. and Ong C.K. 1998. Biophysical interactions in tropical agroforestry systems. *Agroforestry Systems* 38:3-50.

Rani Batish D., Kumar Kohli R., Jose Shibu. and Pal Singh H. 2008. Ecological basis of agroforestry. New York. CRC Press.

Rao M.R. and Coe R.D. 1991. Measuring crop yields in on-farm agroforestry studies. *Agroforestry Systems* 15: 275-289.

Schnepf R. 2003. Iraq's Agriculture: Background and Status. Congressional Research

Service. Available at http://www.nationalaglawcenter.org/assets/crs/RS21516.pdf Accessed 2012-01-12.

Schroth G. and Lehmann J. 1995. Contrasting effects of roots and mulch from three agroforestry tree species on yields of alley cropped maize. *Agriculture, Ecosystems and Environment* 54:89-101.

Svensson S-E. and Hansson D. 2008. Jordbearbetning och sådd av grönsaker. In: Ascard, J. and Bunnvik, C. (red.) 2008. Ekologisk odling av grönsaker på friland. Kurspärm, Jordbruksverket.

Thevathasan N.V. and Gordon A.M. 2004. Ecology of tree intercropping systems in the North temperature region: experiences from southern Ontario, Canada. *Agroforestry Systems* 61:257-268.

Thomas R. 2007. Increasing the Resilience of Dryland Agro-ecosystems to Climate Change. *SAT eJournal.* Volume 4. 1:1-37.

Tubileh A., Bruggeman A. and Turkelboom F. 2004. Growing Olives and Other Tree Species in Marginal Dry Environments. *International Center for Agricultural Research in the Dry Areas*. Available at http://www.icarda.org/docrep/Books/Growing_Olives/Olive.pdf Accessed 2012-04-17.

United states Department of Agriculture. 1996. *Agroforestry Technical Note No.1*.

University of Missouri Center for Agroforestry. Training Manual for Applied Agroforestry Practices. Available at http://www.centerforagroforestry.org/pubs/training/index.php Accessed 2012-01-25.

Van Noordwijk M. and Purnomosidhi P. 1995. Root architecture in relation to tree-soil-crop interactions and shoot pruning in agroforestry. *Agroforestry Systems* 30:161-173.

Wiersum K.F. 1991. Soil erosion and conservation in agroforestry systems. In *Biophysical Research for Asian Agroforestry*. 209-230. New Dehli: Winrock/Oxford & IBH.

World Bank, 2004, sustaining Forest: a development strategy. Washington, DC: World Bank, Appendix 2. Available at
http://www.powells.com/biblio?show=Softcvr%2520W%252fComp%2520Media:Sale:0821357557:%252020.00
Accessed 2012-04-28.

World Weather Online. 2011. Kalar Weather, Iraq Weather Averages. [Online]. Available at: http://www.worldweatheronline.com/Kalar-weather-averages/As-Sulaymaniyah/IQ.aspx
Accessed 2012-05-11

Young A. 1997. *Agroforestry for soil management.* 2nd ed. Nairobi, Kenya: CAB International in association with the international Centre for Research in Agroforestry.

Ögren E. 2003. Gröngödsling i ekologisk grönsaksodling. In: Ascard, J. and Bunnvik, C. (red.) 2008. Ekologisk odling av grönsaker på friland. Kurspärm, Jordbruksverket.

13. Appendix A

Maps showing Kalar, in south of Kurdistan: