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Topic:

Extension of a Permaculture Garden/ Cultivation of Bees

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1. Introduction

1.1 Description of the organization

The name of the organization, where the practical internship was completed, “ Obrobibini Peace Complex (OPC) ” is composed of the Twi words Obroni, which means white man, and Obibini, which means black man. OPC is a Non-Governmental-Organization (NGO), and was founded in March 2018 with its headquarters in Zurich, Switzerland. The first actual place abroad, where OPC operates, is on a four acres big oil palm plantation close to a rather poor fishing village named Busua in the Western Region of Ghana. Like the name already reveals, it is a place where people with all kind of different nationalities, religions and cultural backgrounds, no matter what skin colour they have, live and work together in a community in order to build a place which supports the health of the people and the environment.

The village of Busua inhabits around 2000 people and is well known in Ghana for its unique beach and its growing surfing scene, which makes it an attractive destination for tourists as well. Most of the inhabitants earn their salary through fishing and farming even if the knowledge about farming practices in the Western Region of Ghana is rather low compared to other parts.

The mainly performed technique all over Ghana is a Slash-and-Burn agriculture through which the fertility of the soil decreases already after around 3 years, causing the farmers to abandon the land or use mineral fertilizer and chemical pesticides to maintain productivity (Abebreste, 2002). Even though the oil palm is native in West Africa, the method of farming in big monocultures is destroying native habitats and leads to soil erosion (WRM, 2001).

In the future the main goal of OPC therefore is to build a center of learning, where local farmers can look into a sustainable way of farming and learn new methods through practical examples. Furthermore a healthy way of living through nutrition, herbal medicine, recycling and renewable energies will be taught. With the help of these practices OPC wants to support the local community confronted with the problems of soil degradation, food shortages, environmental pollution and general hygiene problems which lead to health problems. Another important intension is to give the workers the freedom to unfurl themselves in what they do and include their thoughts and ideas in the working process, which helps to create a good working climate and motivates the team.

1.2 Description of the activities

To organize the work on the farm a council meeting was held every week to share ideas, set goals for the next week and discuss problems and reasons why particular goals couldn't be achieved so far. Additionally smaller meetings in the different teams such as building, agroforestry and gardening were held nearly every second day to allocate the work on the field.

Besides the main projects, the garden extension and the bee cultivation, other daily jobs had to be done on the farm. While equipment like a solar panel, a water tank and an irrigation system for the garden were already placed at the farm, other things such as an earth closet, a bucket shower, a washing station and a covered place to hide and gather for meetings had

to be implemented first in order to make an actual living in a bigger community possible on the ground.

Moreover daily jobs like watering and weeding in the garden were done as well as helping with building the first platform, harvesting the oil palms and also helping with the implementation of a dynamic agroforestry system in the plantation. Furthermore an important part of working for OPC was to bring and sell the harvest from the vegetable garden to lodges, tourists or bigger markets in town. However, in the following work the main focus will be on the extension of the permaculture garden and the cultivation of bees.

2. Extension of the permaculture garden

2.1 Introduction in permaculture

The concept of permaculture, which was founded in Australia in the late 1970s, describes a sustainable way of living that tries to combine the major needs of humans, animals and plants in one system through supporting each other in the production instead of seeing every part as an individual one (Mollison, 1981). Permaculture's central idea is that humanity can reduce the pollution-intensive industrial technologies, especially in agriculture, where harmful synthetic substances are used, through the intensive use of biological resources and thoughtful, holistic designs, patterned after natural ecosystems (Morel et al., 2018).

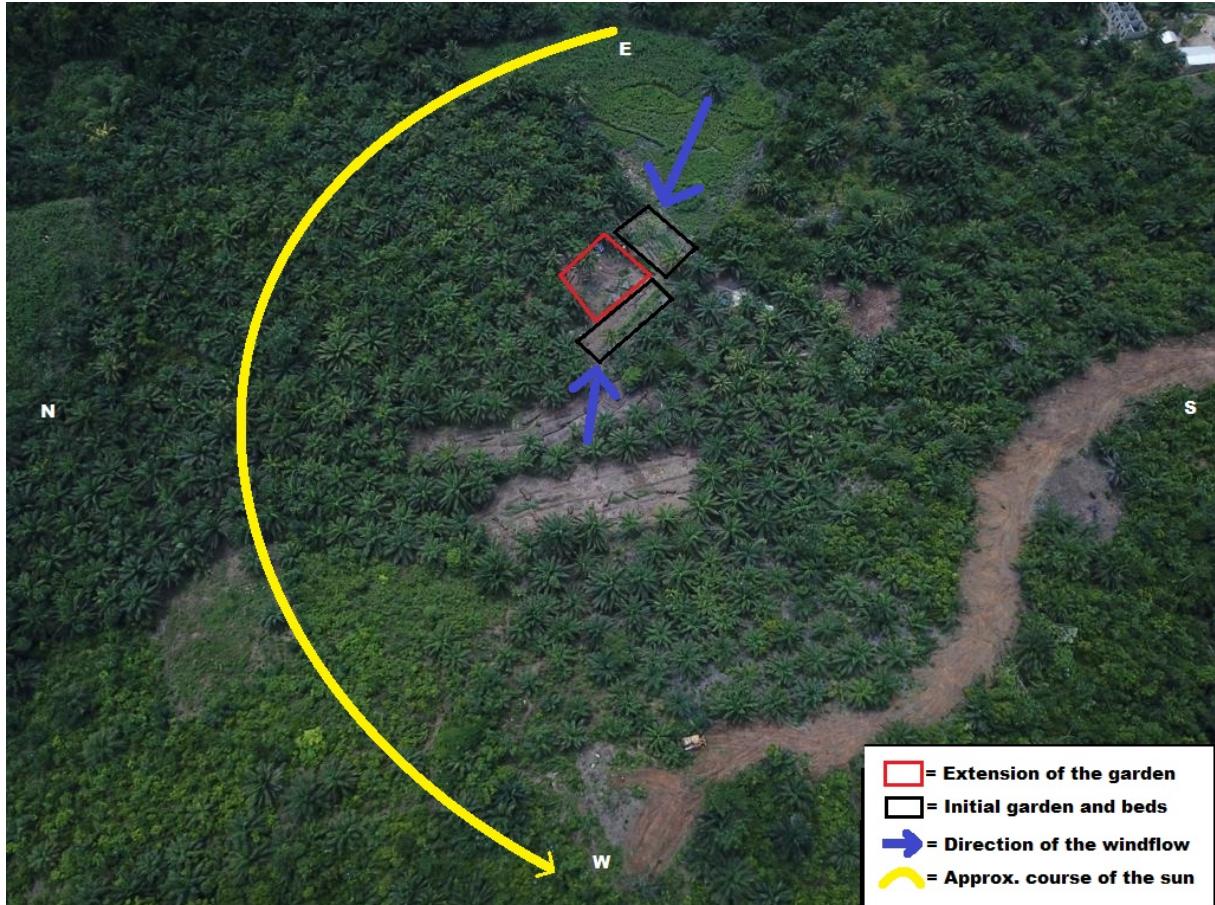
In a permaculture garden all different natural factors, which are already given, such as sun, water, wind, soil and plants and those which are not given from the beginning, such as fruit trees and crops, are considered and combined together as productive as they can be, depending on what is needed in a certain place. Therefore the human, in his role as the manager or designer, tries to direct and edit the natural flow in order to close the natural cycles, using even the smallest water drop as efficient as possible.

2.2 Observations

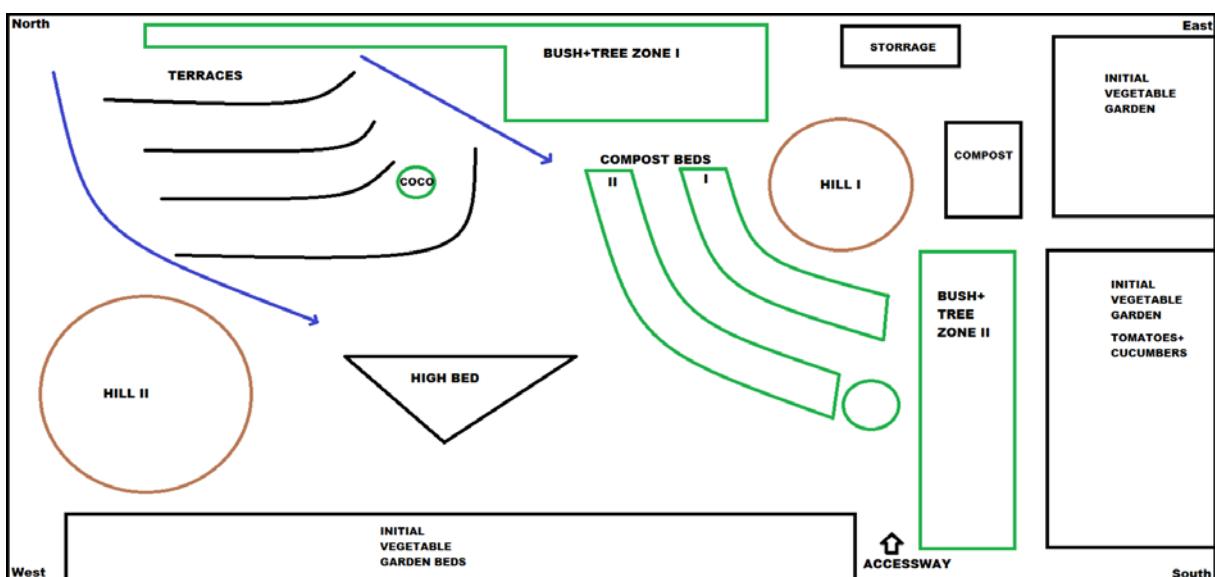
The climate of Ghana is tropical and divided into wet/rainy seasons and dry season. In the south of Ghana two wet seasons occur from April to July and September to November (Dickson and Benneh, 1988). Moreover in the monsoon area in the south-west of Ghana, where the OPC farm is located ($4^{\circ}48'N$, $1^{\circ}56'W$), the humanity is higher compared to the rest of the country (Beck et al., 2018).

The area, where the permaculture garden was extended, is located right next to the initial vegetable garden on the hillside as viewable on the drone picture beneath. Like at the rest of the farm, oil palms were growing in that area before they were cut down in the end of 2018 to make place for a garden. The reduced growth of the palms on that hillside compared to the down part of the farm already indicated a bad condition of the soil. Through the location on the slope the first layer of fertile soil got mostly washed away, leaving red, hard topsoil dominated through mostly rocks, smaller stones and sand, which made it hard to work there especially during the dry season.

Before getting started with the extension of the permaculture garden at OPC observations such as the movement of the sun, the wind and the water were necessary to plan a clever way of placing beds. Even though water would come from the whole hillside in the rainy season, two major streams were identified as the most important and marked in blue on the garden plan below. The wind was mostly coming from an open manioc field from the east, but smaller winds coming from the west were also recognized.



Drone picture of the whole farm ($4^{\circ}48'N$, $1^{\circ}56'W$) (Source: Dr. Christian Andres)



Closer plan of the permaculture garden extension (Source: Own illustration)

2.3 Implementation

One of the first goals set in the meeting was to plant trees and bushes on the sides of the vegetable garden to prevent the wind from hitting the already planted, high tied up cucumbers and tomatoes, which are very sensitive towards strong winds and easy prone to diseases while in stress. The land itself was one big open space, allowing the wind and the water to rush through very fast, carrying nutrients away and damaging the plants. Natural borders were necessary to direct the wind and the water and to create different zones. Therefore trees such as *Moringa oleifera*, *Gliricidia sepium*, *Carica papaya* and bushes such as *Citronella*, *Solanum torvum* (Turkey berry) were planted close together in the “Tree and Bush Zone 2”. *Citronella* can be used all around the garden and close to the beds or even in the camp as a natural insect repellent. *Gliricidia sep.* is one of the best rated nitrogen fixing trees in the tropics and therefore necessary all around the garden as is *Moringa*, whose leafs can be pruned heavily and consumed or used as a high quality mulch. In the “Tree and Bush Zone 1” *Moringa*, *Citronella* and papaya were combined together with *Hibiscus*, *Persea americana* (Avocado) and *Gmelina arborea*, which is a fast growing timber tree. This combination of trees was also planted in between the terraces and the high bed to function as a biomass producer that can be pruned heavily. On the first hill mostly the green variety of the chili pepper *Capsicum chinense*, which is known as a perennial that can be harvested over the whole year and used in nearly every Ghanaian dish, was planted together with local *Ocimum basilicum* and one *Hibiscus*. As for the second hill, the plan was to introduce and remain health beneficial herbs and therefore only a few pepper plants were put in between. All the plants were marked, so it would be easy to recognize them during the weeding, and mulched afterwards.

Due to the low fertility of the soil on the slope it was necessary to bring more external biomass into the system. Luckily it was possible to obtain sawdust for free from the next town and purchase chicken manure from the chicken farms. Additionally at least twice a week food leftovers and coconut shells were collected from the town with a wheelbarrow to build up a decent compost, which could be used to nurse young plants or put directly into the beds.

Because of the location on the slope and the associated problem of the water, running down the hill in the upcoming rainy season, different methods of farming compared to the garden in the valley had to be introduced:

1. Compost Beds
2. Terraces
3. High Beds

1. Compost Beds

The first beds placed were the half circled compost beds around the first hill. Some fresh compost, fresh and rotten palm leafs and some bigger sticks were buried around the first hill in a formation of the quarter of a circle. Afterwards soil was put on top again and a small stream in front of every bed was dug, so the water, which runs down the slope, could leave some nutrients in there while flowing around the beds. It was necessary to pick out the palm

oil roots from the soil before it was put on top again, because if not done, the soil is very likely to compress through the rain. Additionally biochar was added to the inner of the compost, so nutrients, especially nitrogen from the fresh compost and the leaves, could be fixed there and stored for a longer term. The result were compost high beds, which not only prevent the seeds and plants from getting washed away, but also direct the water flow coming down the hill through the tree and bush zone towards the vegetable garden. Because the whole bed had to settle a while before it was possible to plant something, the leaves from the pruned oil palms and weeds on the farm were shredded and used as a top layer to protect the bare soil from erosion and dehydration.

After the beds were settled, *Zea mays* (Corn) and *Vigna unguiculata* (Black-eyed bean), which are known as a beneficial combination, were planted in the first compost bed and one week later *Ipomoea batatas* (Sweet potato) was added. Normally it's kind of an exhausting search when the sweet potato is planted on the flat ground and not all fruits can be found, so in order to simplify the harvest process, it was planted in the high compost bed instead. This way the sweet potato would be able to cover the ground in the direction of the first hill, where the pepper was planted, while the beans would be forced to climb up the corn.

In the second round bed a combination of *Beta vulgaris* (Chard), *Abelmoschus esculentus* (Okra), *Solanum lycopersicum* (Tomato) and different varieties of *Spinacia oleracea* (Spinach) was planted. A small part with wild local herbs including one herb which is called "ajampong" (Scientific name unknown) was left at the end of the bed (Marked as a round circle on the plan). Because of its disinfecting impact it helps to cure cuts, which can happen a lot while working with a cutlass, much faster than conventional medicine (Personal experience).

Also trees such as *Moringa* and *Annona muricata* (Soursop) were planted on the very top of the beds so the roots could prevent erosion. Furthermore after some months a special grass, which is used in slopes to prevent erosion, was introduced to the place and planted above the beds and between the terraces.



Source: Own photography (Including following pages)

2. Terraces

To build the terraces, stems of bamboo were fixed horizontal in between the rocks on the slope and adjustments of the soil were made to create four new levels in a place, where it was nearly impossible to farm before. For the lower terraces an oil palm was also turned around and used as a wall, building a good climbing place for beans later on. In order to fill the terraces a lot of organic matter had to be carried on top of the hill, which emphasized to be a lot of work. To reduce the work a shredder was placed on top of the hill, so that every kind of biomass lying around could be shredded and put directly in the beds. Then plenty of wheelbarrows with sawdust, chicken manure, compost and soil from a dug up drainage in the valley were carried to the terraces.

Because of the location on top of the hill it is difficult to include the terraces into the irrigation system, which is necessary in the dry season. Therefore mainly perennials were planted, so it would not be too much work to water the plants by hand if necessary. Right on top of the first terrace an almond tree was planted around useful local herbs as well as some *Aloe vera*. On the second stage below, which could be abandoned in the dry season, were tomatoes planted and supported by local *Basil*. The two lowest stages were dominated by local perennials such as *Taraxacum* (Dandelion), *Senna alata* (a local herb against skin diseases), *Cymbopogon citratus* (Lemongrass), spice leafs and *Hibiscus* but on the lowest terrace *Lactuca sativa* (Lettuce) and *Piper nigrum* (Black Pepper), which was supposed to climb up the coconut palm, were planted as well.



View of the terraces from the top during the construction (left) and afterwards (right)



3. High Bed

In the middle of the slope a high bed was built out of cut down oil palms, which would decompose after some month during the rainy season. The palms were put in position and used as walls in the form of a triangle. Like the terraces the high bed was filled with all kind of organic matter including biochar and covered with soil in the end. Because of the location right in the middle of the slope, where the water stream would flow in the rainy season, the triangle high bed was supposed to be the center of energy, spreading the nutrients down to the lower beds once the oil palms were decomposed. This way the area around and especially beneath the high bed, where a lot of mulch was stored, would be very fertile after the rainy season.

In the middle of the high bed *Citrullus lanatus* (Watermelon) and spinach were planted, surrounded by lemongrass in each corner. After the maturity of the watermelon the bed was completely filled with different types of spinach and a grit out of palm sticks was build, so the spinach could climb above the ground and inside the lemongrass. Around the high bed spice leaves and beans were planted to climb up the oil palms and a row of papayas was placed below in the mulch.



2.4 Results, Problems and Solutions

2.4.1 Process of the extension

The following pictures (From the top left to the bottom right) show the development of the permaculture garden in between the 07.04.19 and the 11.07.2019 (View from the first hill):



2.4.2 Harvest of the beds

In the first round bed, where corn, sweet potatoes and beans were planted, it was observed, that neither of the three had problems with diseases compared to when they were planted separately. The sweet potato covered the ground in direction of the first hill and could always be pruned back to stimulate more growth. The beans overgrew the corn and even destroyed parts of them at the peak, which led to a much lower yield compared to when the corn was planted alone. All three different crops could be harvested, but it has to be considered that the corn would have brought higher yields without the beans. However, the beans ensured the health of the corn as long as they didn't overgrow it, so eventually the beans have to be cut back in an early stage or the combination of beans and corn could be enough in one bed. This way the beans could cover the ground instead of the sweet potato.

From the combination of spinach, dandelion, chard, tomato and okra good yields were obtained, but the spinach showed a much better growth than expected and can therefore occupy a bigger space than the second round bed. The chard could only be harvested for one

month and stopped to produce leaves afterwards. Reasons for that could be the different environment or the high pressure of pests, which will be elaborated closer later on.

On the terraces only the black pepper was not able to grow big enough to climb up the coconut palm, while the rest, especially the herbs, showed a sufficient growth. On the lowest terrace too much sawdust was applied, which made the soil to acidic for vegetables. In general, when applying a lot of external biomass like sawdust and chicken manure the right c: n ratio has to be considered.

The fertility of the upper soil layer in the high bed was very low in the beginning, so the watermelon couldn't develop well enough, but instead a lot of mushrooms, which are known to occur in the decomposed oil palms during the rainy season, grew in the mulch around the watermelon after the first rains. Also the lemongrass, an eatable weed and beans, which were growing around, could establish good. The daily harvest of spinach was enough for one decent meal on the farm.



Beans overgrowing the corn



Mushrooms in the high bed

2.4.3 Germination rate

In the beginning it was hard to figure out which seeds from Europe would germinate in the tropical climate in Ghana. Radish, beetroot and lettuce from Europe were already introduced successfully, but many other seeds like broccoli, different herbs and flowers from Europe couldn't germinate either in the open field or in the nursery, while others needed more than one month until they germinated.

As for the basil and for most of the other European herbs only one out of ten seeds germinated. However, dill could establish very well next to the cucumber and approximately

every second seed germinated, even though the first came out after one month. The European white and chinese cabbage strains germinated best with a germination rate close to 90%.

Germination rates were higher in the rainy season as long as the seeds didn't get washed away. In the dry season the seeds should be watered every day and nursed in a sheltered place to protect the germ buds from the sun and strong winds. A plant nursery can also help against chicken and other birds, who try to eat the seeds. If seeds are directly planted in the bed, a roof out of palm leaves can build in order to protect the young plants against the sun and prevent the dehydration of the soil.

2.4.4 Pests and diseases

European tomatoes, eggplants and cucumbers were already growing in the beginning, but attacked by a bacterial disease once they reached the stage of fruiting and were therefore not able to produce healthy fruits. Since the tomatoes and the cucumbers were tied up, the strong winds on the land stressed the plants a lot, making it harder for them to fight the diseases. It was observed that the extent of these diseases was much lower on tomato plants, which were growing directly on the ground. Also a right and clean procedure of pruning made an impact on the plants health, but in general also other plants like eggplants or paprika for example looked healthier and produced better fruits, when they were kept rather bushy. So it is recommended to cut the main steam of the tomato at the right time so a minimum of two side sprouts can develop healthy on the ground. Still a small support can be build, so the flowers and the fruits don't touch the ground.

Not only the tomatoes had to fight with diseases, but bugs were destroying the crops all over the garden, especially the cabbages were eaten extremely fast. Since spraying chemicals is not an option in organic farming, natural methods against the insects had to be used. Mixtures out of garlic, chili and ginger were applied without showing any effect. Only the Neem-Oil, which is won from the seeds of the neem tree and sprayed mostly in the rainy season, could show an improvement. But from own experience the only substance, which worked against all insects, was the Bamboo-Vinegar. It was first discovered as an insect repellent by a German, who lives and works in Ancobra Beach close to Busua. From his experience the distilled Bamboo-Vinegar combined together with other substances also enhances root growth of the plants when applied directly on the ground and underneath the leaves. However, indeed it worked very well as an insect repellent when applied every second day or after a rain. Both, Neem-Oil and Bamboo-Vinegar, are known to not be harmful to beneficial insects, but can only be used while the plants are not in the flowering stage, which makes it very useful especially for cabbages. But in the long term the continuing diversification of the whole area with more perennial plants will work as the best protection against pests and diseases.

2.5 Outlook

Once the compost and the leaves in the high bed, the terraces and the compost beds are decomposed, an improvement of the soil's structure should be recognized, but it is necessary to plant more biomass producing trees, so the soil can be mulched permanently. In the beds and on the terraces different trees from the seeds in the compost will pop up

and can either be used as a biomass producer or left to produce fruits. Even though the green pepper is producing good and doesn't show any symptoms of sickness, it would still help to diversify the first hill with local herb to prevent diseases.

For the dry season it could be useful to integrate a water tank on top of the hill, so the water can be collected and the terraces irrigated if necessary. Once a water tank or a pond is placed there on top, labor can be reduced and the beds on the slope can be extended. Also the bee hives, which are placed on top of the hill, will need a fresh water source once the population starts to grow.

3. Cultivation of Bees

3.1 Introduction in Beekeeping

The activity of beekeeping is commonly understood as maintaining bee colonies in human-made hives. As a kind of compensation for caring and managing the bees by providing hives, the beekeeper can collect honey and other products, such as wax, pollen, royal jelly and propolis, in return.

The economic value of beekeeping in developing countries can be extremely high as it provides a source of income and nutrition for the rural people and in the meantime also is beneficial for the environment, because of its economic reasons for the retention of native habitats (Jones, 1999). But the greatest ecological value for the environment and the farmer is mainly dedicated due to the role of bees as pollinators of flowering plants. Bees are the most important pollination group among all insects (Michener, 2007). In fact, bees and other pollinators affect 35 percent of the global agricultural land, supporting the production of 87 of the leading food crops worldwide and are, at least partially, responsible for ca. 75% of the world's crops producing fruits and seeds for human consumption (FAO, 2018).

With only one bee suite and self-made hives it seems to be easy to start a business in beekeeping even in rural and low developed places, but in the area around Busua honey hunters normally destroy a whole colony of wild bees to be able to collect their honey. Also the use of pesticides around the farming land influences the bees and forces them to hide in the forest, making it more difficult to catch and colonize them properly. This is why a sustainable way of honey production in the form of beekeeping combined together with organic farming has to be accomplished in order to protect bees and maintain their important function for the agricultural land and the whole ecosystem.



Bee hives at OPC



Wild bee colony

3.2 Implementation

To cultivate bees, at first swarming boxes and bee hives were manufactured for OPC. The swarming boxes could already function as small hives as they provide the top bars, where the bees start to build their honeycomb structure. But they are rather small, because they had to be hung in a tree in order to catch a swarm, so bigger hives had to be placed on the ground as well (Picture above). Besides the hives, protective clothing, including an overall, head veil, gloves and shoes, and a smoker, which is used to reduce the ability of bees to fly and sting, are needed when starting a beekeeping business. The swarming boxes were rubbed completely with bee wax and lemongrass to attract the swarms and were then hung in different trees close to the farm and in the forests.

As for the position, the box should be hung on a tree that's either higher than the rest of the forest or right next to an open field, so that the bees are able to find the box easily but also feel safe through the overview that's offered. It is important, that the bees can find enough water and food in the closer surrounding in form of flowers from mango, avocado, citrus or almond trees for example. Also important is that the surrounding is mostly free from disturbances like loud voices, strong vibrations, fires and natural enemies, which are small animals or other insects, especially ants. Therefore the box had to be observed every second day to make sure that the bees are not getting disturbed or can't even choose the box as a possible home, because of the presence of ants.

For the location of the hive on the ground it is also important that food and fresh water is close, while loud noises and settlements in general should be at least a couple 100 m away. Also important is that the hive stands slightly shaded under a tree and doesn't get affected by strong winds. In order to protect the bees against predators, the hive was placed one meter high on a metal construct and small cups of water were put under each metal stick on the ground, so insects couldn't climb up and disturb the bees. A metal sheet was put on top to protect the hive from the rain and the level of the entrance had to be slightly beneath the rest so water couldn't flow in.

After some translocations the first swarm was caught in the boxes and had to be transferred to the bigger hive on the ground. This had to be done at night, because then the bees are

less aggressive and only a few are gathering outside the box while it is dark, except when the colony gets too big and wants to divide as viewable on the two pictures below. The box was carefully brought down and then fogged in smoke so all of the bees would hide inside the box and the entrance could be blocked with a piece of cardboard. Then the box was carefully carried to the hives on the ground, where it was put on top and left there for three days so the bees could get familiar with their new environment. After the acclimatization period the bees were transferred again at night into their new home, the hive.



Bees gathering around a swarm box



Bee transfer from the box to the hive

3.3 Results, Problems and Solutions

During the practical internship three bee colonies were transferred to the hives and actually settled there as well. Other swarms, which were caught and transferred, were either driven out by ants, which used a fallen branch on the hive to enter it and kill the bees, or forced to leave, perhaps due to a missing supply of water and food around the hives.

There are many possible reasons for the bees to leave the hive again, when the management is bad, but one of the most important points is the location of the hive. As mentioned above bees react very sensitive to noises and vibrations and therefore should be held far away from bigger machines, animals and human settlements. They also have to be protected from chemical poisoning in the air by conventional farms for example and are dependent on the supply of food and water. If the managing is poor also pests and diseases are likely to threaten the bees, leaving a bad harvest for the farmer, forcing him to abandon the beekeeping (McGregor, 1999). That's why it is important to control the hives and the surrounding daily and observe the behavior and the movement of the bees.

A problem while transferring the swarms or harvesting honeycombs is a too intensive use of the smoker directly into the entrance of the hive. This way the bees can suffocate and the harvest can be contaminated. Therefore and for other reasons it is always useful when two people do the transferring of the swarm boxes, so one can use the smoker, while the other one does the transfer.

The colony strength is the highest, when the supply of pollen is the highest. During that period high yields can be achieved while harvesting the honey. It's recommended to collect the honey three to four weeks after the honey flow period, which is the time when many plants, that provide nectar, are flowering at the same time (FiBL, 2011).

In general it seems to be easy to catch and keep bees as soon as protection clothing and hives are provided, but the decisive part is the successful managing of the bee colony. Most of the farmers are not aware of the necessary "know-hows" of managing bees, why it would be important to provide long term courses for local farmers so they can learn how to establish a successful beekeeping business and therewith also maintain biodiversity.

3.4 Outlook

Once the bees are established well enough in the OPC hives, second hives have to be placed on top of the first ones in order to harvest pure honey. These hives only have a thin net on the bottom, allowing the queen not to pass through and lay eggs in it. This way the queen can only produce eggs in the bottom hive while workers, which can pass through the net, can produce clean honeycombs in the second hive. If this is not considered, it will be difficult to harvest quality honey from the hives in the near future.

However, the chances of establishing a successful beekeeping business at OPC are extremely good since a lot of potential nutrients for the bees have been planted in the agroforestry and the permaculture garden. But as mentioned above, a fresh water source should be implemented closer to the hives, because otherwise the bees are going to have difficulties in the dry season.

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