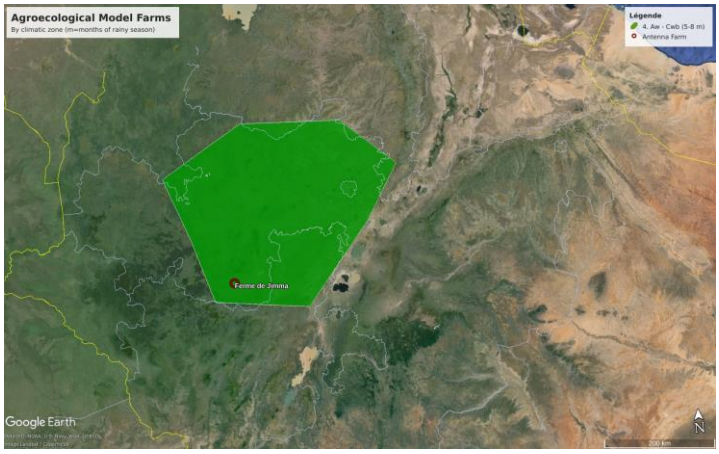
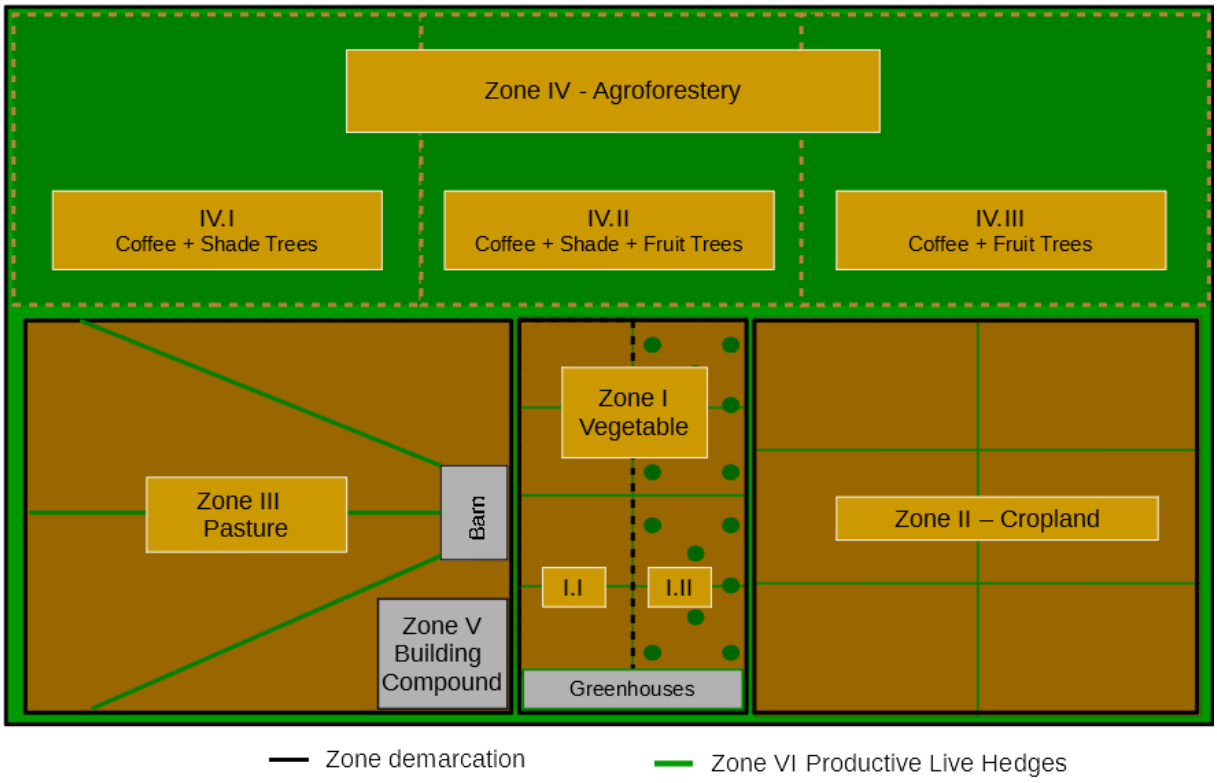
1. Target Zone



The agroecosystem model presented here is designed to produce the commodities consumed by the people of the horn of Africa, including vegetables, cereals, coffee, milk, chicken meat and fish. It is designed to produce without the use of chemical and /or external inputs, including pesticides and fertilizers. The farm integrates agroforest-based coffee, cereal, vegetable, livestock and fish production unit. The farm is designed for a subtropical highland climate (Cwb) with an altitude between 1000 and 2500 m, a rainy season of 6 to 8 months and annual precipitation ranging between 1000 and 2000 mm. The model farm can be used for other regions with subtropical highland climate, but the selected crops must be adapted to the local demand.

2. Agroecosystem Overview

The agroecosystem model farm is divided in (i) vegetable production zone, (ii) cropland zone, (iii) livestock production and pasture zone, (iv)agroforestry-based coffee production zone, (v)building compound, (vi) a productive live hedge.



Vegetable production zone (I.I)

5000 m^2, 4 plots of 900 m^2+ separations (400 m^2) + greenhouses (1000 m^2)

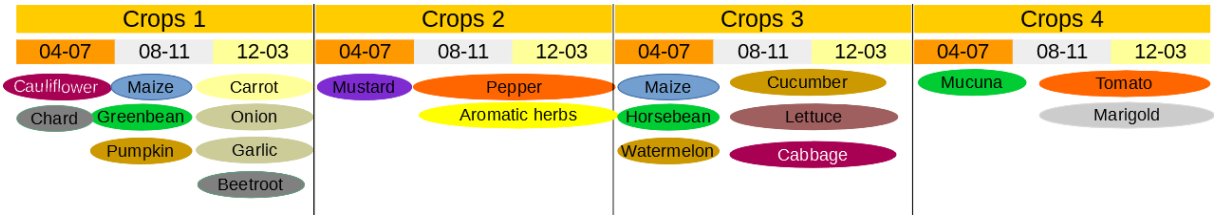
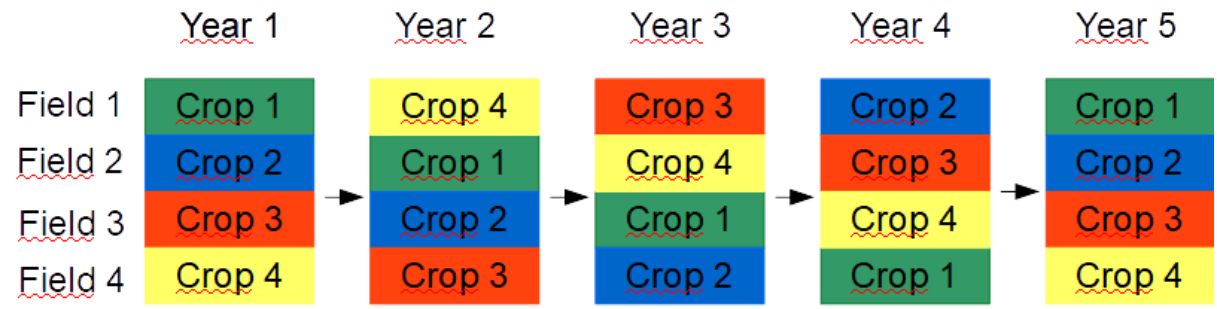


Figure 1 : Crop rotation in zone I.I. Number indicates months. Color indicates the different botanic families.

Zone I.I is separated into 4 fields of 800 m^2. The fields are separated by double rows of pineapples to limit erosion. A further plot of 1000 m^2 is used for greenhouses. Zone I.I is used to produce vegetables intensively. The four plots are watered with drip irrigation and cultivated the whole year. In the rotation (see figure above), we alternate between different plant families to limit pest, disease and weed pressure, as well as between demanding and non-demanding crops to avoid nutrient mining and soil fertility losses. Green manure are cultivated to regenerate (mucuna) or sanitize (mustard) against soilborne diseases. The soil is always covered to limit erosion. The rotation in the I.I zone lasts 4 years, starting on each of the 4 fields with a different crop, then going on chronologically (see scheme below). After 2 cycles of the 4 year rotation, zone I.I is switched with zone I.II (see below), thus the drip irrigation system is moved.



On the remaining 1000 m^2, three greenhouses of 300 m^2 are built. They should provide protection from rain and insects but allow complete aeration and minimum heat accumulation. One greenhouse is used for seedling and sapling production, while the two other greenhouse have two plots, which allow to follow a 4 year rotation as shown below. Irrigation is installed in the greenhouses.

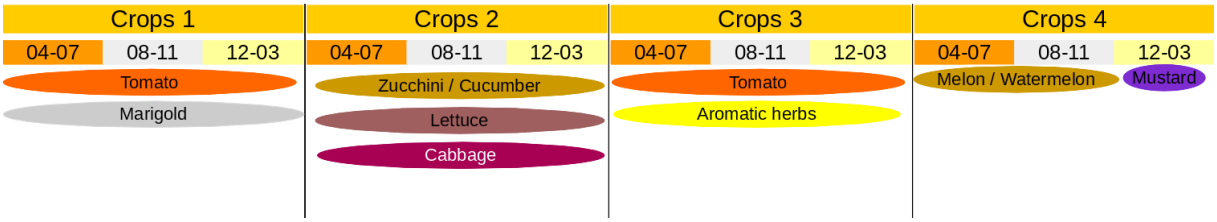


Figure 2 : Crop rotation in the greenhouses. Number indicates months. Color indicates the different botanic families.

Semi-agroforestry production zone (I.II)

4000 m^2, 4 plots of 900 m^2+ separations (400 m^2)

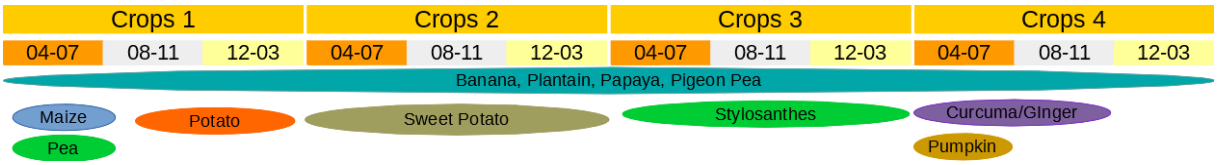


Figure 3 : Crop rotation in zone I.II. Number indicates months. Color indicates the different botanic families.

Zone I.II is separated into 4 fields of 900 m^2. The fields are separated by double rows of pineapples to limit erosion. Zone I.II is used to produce tuber crops. Tuber crops cultivation usually goes along with a heavy disturbance of the soil when planting and harvesting, as well as a slow growth and consequent little ground cover. Thus these soil-endangering crops are associated with fast growing perennials (ananas, melon, banana, pigeon pea), which limit water and wind erosion by intercepting rain and maximizing vegetation cover. The perennials are fast growing tree that rapidly produce fruits, in order to be able to remove the whole system after a few years. Therefore the system is called semi-agroforestry. Zone I.II is mostly cultivated during rain season, except when growing potatoes. Irrigation is made by hand.

The crops in the subzone are likewise cultivated on a 4 year rotation (see above), including green manure and alternating between demanding crops. After 2 cycles of the 4 year rotation, zone I.I is switched with zone I.II (see below). The perennials are then removed and new ones planted in the new I.II plots.

Cropland production zone (II)

13'000 m^2, 6 plots of 2000 m^2 + separations (1000 m^2)

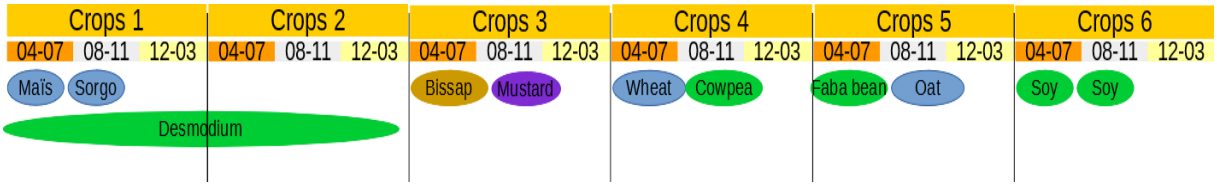


Figure 4 : Crop rotation in zone II. Number indicates months. Color indicates the different botanic families.

Zone II allows the production of calorific commodities in large quantities. These are field crops that are not very sensitive (pests, diseases, drought) requiring little maintenance and water. These crops are grown in the rainy season only and are not irrigated. Zone II is separated into 6 fields. The fields are separated rows of brachiaria or elephant grass, which help limit erosion, produce fodder and control cereal pests (see pest control). A row of brachiaria or elephant grass is also planted on the outer sides of the fields (at the foot of the external hedges). It is indeed necessary that the fields are surrounded by the grasses for the effectiveness of the push-pull system (see pest control).

A rotation of 6 years is installed, starting on each of the 6 fields with a different crop (same principle as in zone I). Cereals and legumes are mainly grown. Green manure (desmodium) regenerates the soil and biofumigation (Mustard) sterilizes it from soilborne diseases. To limit the risk of pests and diseases, we alternate between crops from different families between the years. Rotation in Zone II contains only crops that do not require soil turning for planting and harvesting. Minimal tillage is therefore possible. This area is cultivated in direct sowing with permanent vegetation cover (see chapter tillage). The soil is never ploughed and is always covered: either by a crop, or by mulching of the previous crop.

Pasture production zone (III):

18’000 m^2 : 4 plots of 4’000 m^2 + separations (1000 m^2) + animal enclosure (1000 m^2)

The pasture zone is divided in 4 plots of 1000 m^2, separated by densely planted rows of pigeon pea. Fodder crops (legumes and grasses) are sown in the different plots. Animals are feeding on one plot while the others are protected to allow the vegetation to grow back. A few trees are planted to provide shade. The animal enclosure is located in the middle and contains a barn with a permanent outside access.

Agroforestry production zone (IV):

24’000 m^2: 3 subzones of 8’000 m^2

Zone IV is a coffee production intercropped with different trees. Coffee is intercropped with legume trees in the whole zone. The different subzones are differentiated by the further species intercropped with coffee.

In subzone IV.I, coffee is planted under existing shade trees. The forest is cleared and the chosen shade trees are left alive before planting coffee. If a forest is not available for the plantation, local essences of shade trees can be planted.

In subzone IV.II, coffee is intercropped with fruit trees (avocados, papaya, banana) under the existing shade tree (or under planted shade trees of local essence).

In subzone IV.III, coffee is intercropped with fruit trees in open land (no further shade trees).

The Trees of different size and shape are planted to optimize space and shading. At the beginning, the trees must be protected from the animals, but when they are big enough, the zone can be used as a pasture. Once the system is implemented, a subcover of mucuna planted and stays indefinitely as ground cover and pasture.

Productive hedges (VI): 1500 m^2: The hedges are raised for wind, pest and disease protection, as well as for retaining water in the system. The hedges are made with fast growing legume and fodder trees.

Building compound (V): 1500 m^2: Storage and warden house, toilet, groundwater well with water tower, fish pound and sapling nursery.

3. Water Management

Groundwaterwell and irrigation: Access to water in sufficient quantity is important for the productivity of the system. A borehole with solar pump and water tower are therefore built in the built-up area. The water tower must contain between 10,000 and 20,000 L with a pump of a flow rate of 5,000 L/h. This quantity should supply water to the vegetables in zone I and the trees in zone IV during the dry season. Irrigation is done using hoses. Other crops in zones II, III and hedgerows are never watered once the system is installed. On the other hand, saplings in the hedges must be watered for the first 2 years. Furthermore, water is used for the fish production and for animals to drink.

Cultivation on ridges: Some crops (sweet potato, potato are cultivated on ridges. By doing so, water will be retained and available for the crops in the furrows and on the ridges. At the same time, the tubers are protected from rotting in case of water stagnation. Erosion is furthermore limited as the ridges are build perpendicular to the slope.

Growing in small Zai holes: Holes 10 cm deep and 15 cm wide are dug and filled with a manure-soil mixture. The remaining earth forms ridges around the holes so that water concentrates in the holes. The vegetables are then sown or transplanted in the holes where nutrients and water are concentrated. Zai holes are used during dry season and are dug in the raised beds for water intensive vegetables such as tomatoes.

Drains: To avoid flooding, the landscape must be prepared to allow excess water to flow out of the fields. Drains and ponds must be dug according to the topography. The pond can be used to raise fish and allow animals to wash and water.

Drought-resistant varieties: It is important to choose drought-resistant varieties, either using improved varieties or using local varieties perfectly adapted to the climate.

4. Soil Management

Intensive soil returning, together with uncovered soil exposure, are practices responsible for a degradation in soil fertility through high erosion and decomposition of the organic matter. This is why direct seeding with permanent vegetation cover is strongly advised. The soil is worked only superficially and locally where the seed or seedling will be planted. The absence of a hard crust is thus needed. A permanent vegetation or mulch cover is essential to prevent the formation of a crust, while also protecting the soil.

The first year, the plot is cleared mechanically, and the soil is ploughed by animal traction at a depth of 20-30 cm. The harvested biomass can be used as mulch in the first season or be composed or fed to the animals. The following years, no ploughing will occur, except in zone I. When the crop is harvested, the biomass is partly fed to animals partly left as mulch, and the next crop is planted under the mulch by opening the soil at the specific locations only. Weeds must be removed by hand.

The mulch is also useful to maintain humidity and protect from damage of heavy monsoon precipitation (erosion, disease spreading, plant injury). Mulch must be in priority applied to crops with low soil coverage, slow growth or demanding an intensive soil disturbance during planting or harvesting (tuber crops).

5. Nutrient management

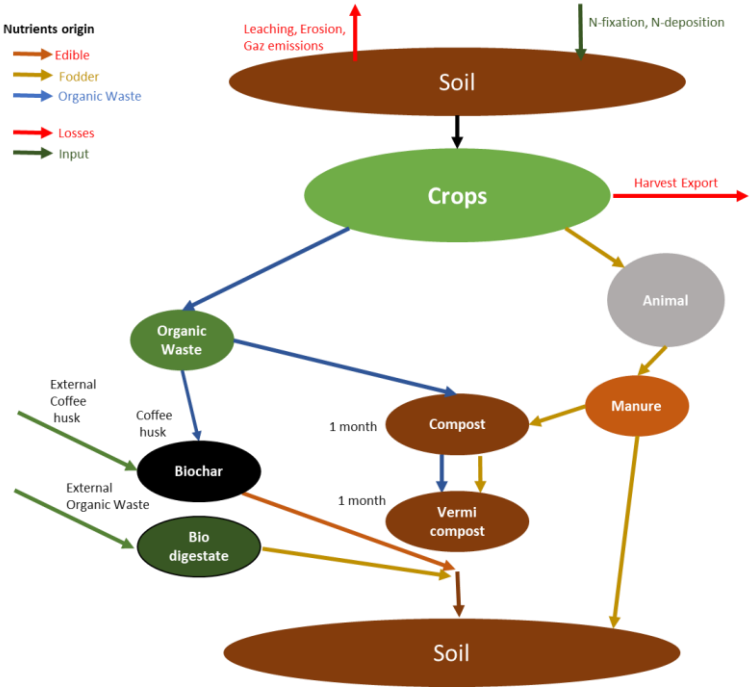


Figure 5: Nutrient cycle in the agroecosystem

Animal manure: Animals may be found in the different plots of zone I, II and III or in their enclosure, depending on the season and their use in the cropping system. When they are located in the fields, their manure is spread to ensure a homogeny nutrient supply but is not collected. In their enclosure, a collecting system must be established. The manure must be stored in a sealed pit, with a cover sheet to limit contact with the air and protect it from the rain.

Organic waste: Organic waste such as kitchen residues or crop residues, which can be eaten neither by men nor animals, are composted before being used as organic amendment. Waste such as maize cobs, coffee husk, nut shells and small wood stems can be transformed in biochar.

Biochar: According to the needs and production capacity, trees from the hedges are cut to use the wood for energy. The woody wastes or other adequate agricultural by-products (maize cobs for instance) are transformed into biochar. Biochar is crushed and amended to the soil to increase its water and nutrient retention. Biochar should be used intensively on sandy soils with low organic matter content, as well as in soil with high disturbance (tuber crops cultivation).

Biodigestate: biodigestate produced out of external manure is added to the system during the years of installement.

Fertilisation: Compost, crushed biochar and biogas digestate must be mixed a few weeks before applying. This mixture, as well as ruminant manure are amended during soil preparation before sowing by incorporating it into the soil to limit volatilisation. Chicken manure is applied at cereal earing an at tuber/root/bulb initiation. For other vegetables, chicken manure is applied at the feet of the crops in 3 amendments: 30% at flowering, 50% at fruit initiation and 30% after the first harvest. Chicken manure is also used as feed for fish, whereas the water of the fish pound is used to fertirigate vegetables. Details for the fertilisation of each specific crop is given on the annexes (crop demand in nutrients + fertilisation advise). The fertilisation advise are given in kg/ha for the whole plots, as well as in g/linear m for the vegetables. To produce enough manure for the whole crop, it is estimated that 9 cows, 8 heifers, 566 chickens, 12 Indian runner ducks and 42 laying hens are needed. It is estimated that 80% of ruminants respectively 100% of poultry excretions (except the ducks) can be gathered and used. The remaining quantities are left on the pasture to fertilize these plots. The following tables summarize the yearly manure need of the different zones, as well as the number of animals needed and the amount manure they produce. Compost, urine and fishwater are used as extra fertilizing in addition to the quantities needed of manure.

Table 1 : Number of animals of each type need to produce sufficient manure for the agroecosystem. Ducks are not indicated, since their manure is not collected.

	Type	Heads	Manure [kg]
Poultry	Laying henn	42	1 415
	Broiler	566	12 804
	Total	**608**	**14 219**
Ruminant	Heifer	8	5 913
	Milkcow	9	13 796
	Total	**17**	**19 709**

Table 2 : Manure needs of the different zones in kg and in t/ha

Manure [kg]	**I.I**	**I.II**	**II**	**IV**	**Fish**	**Total**
Ruminant	4 021	2 532	6 656	6 500	0	**19 709**
Poultry	1 084	538	1 097	6 500	5 000	**14 219**
Total	5 105	3 070	7 752	13 000	5 000	**33 928**
Manure [t/ha]	**I.I**	**I.II**	**II**	**IV**		
Ruminant	10.1	7.0	5.5	2.7	-	**1.3**
Poultry	2.7	1.5	0.9	2.7	-	**1.0**
Total	**12.8**	**8.5**	**6.5**	**5.4**	-	**2.3**

6. Pest and disease management

High biodiversity: The control of pest and disease in this agroecosystem relies on a high biodiversity, on the one hand with a maximum number of variety of the same species, on the other hand on a maximum number of species. This should create a discontinuity of resources and in some case have repulsive effect and thus limit the spreading of pests. It also reduces the risk of disastrous harvest, since the poor harvest of one crop can be compensated by the good production of another.

Adequate plant nutrition: The soil is maintained fertile with organic amendments (see nutrient management) as well as sufficient water, which support the health of the crops and their tolerance towards pests.

Choice of seeds: Ideally, local cultivars known for their ability to resists pests and diseases are used. If the indigenous varieties are susceptible to diseases, resistant varieties from research institutes or private company must be cultivated. Non-reproducible hybrid seeds are not adequate as the system must become autonomous, the seeds for the second season should be produced on-farm.

Vegetative propagation material (tubers, cuttings, rhizomes) should be chosen from healthy plants (no signs of diseases or rotting) with the highest production and should be protected from pest during storage. They should be stored in the shade, at a few meters height to avoid contact with the soil and protected by a straw roof that allow water to percolate on it. Cuttings and tubers should be treated with ashes: 150 g of ashes are mixed with 8 l of water. The vegetative propagation material is soaked for 10 minutes and dried in the shade.

Crop rotation: Crops from different botanic families are grown every year to avoid transmission of diseases and pest from year to year.

Hygiene: Fallen fruits are collected and composted. Sick plants are removed and burnt before the disease can spread.

Poultry: Indian runner ducks are allowed to pasture everywhere the whole time, and thus help fighting pests.

Repulsive crops: Crops secreting pest repellent molecules (ginger, chili, onion, garlic) are used, particularly in combination with susceptible crops, for instance onion as a companion of carrot.

Attractive crops: Flower crops (hibiscus, okra, amaranth, and marigold) are used to attract as much different insects as possible, including pest predators.

Striga in cereals: Striga control is first of all based on maintaining soil fertility, which should limit the establishment of the parasitic weed. Legumes are always intercropped with cereals for this purpose. In case of striga infection, all associated grain legumes should be replaced by desmodium, which provoke a suicidal germination of the weed. Desmodium is anyway associated to maize (see below).

Stalk borer and fall armyworm in cereals: Stalk borer and fall armyworm in cereals (mostly maize) are controlled using the push-pull technology. Desmodium associated with cereals repel the pest, while a row of Napier grass around the field attract them and kill them. In dry areas (<900-1000 mm), it is advised to use the grass brachiaria instead of Napier. In the absence of pests, desmodium can be replaced by a grain legume, while in case of infection, desmodium should be planted instead of grain legumes. Brachiaria, Napier and desmodium are high quality forage.

Termites: Visible termite mounds should be destroyed mechanically, the queen located and killed. The mound is clay rich and can be amended on sandy soil to improve water and nutrient retention. Crops must be healthy and well-fed, and hydric stress should be avoided since termites feed on dry material. In case of high termite pressure, sorgo and mil should be favoured over maize, Bambara bean and cowpea over groundnut. A mulch can be applied on infected plots, as it will provide alternative feed for the pests and divert them from the crop. However, it can also sustain termite population and worsen the infection. The evolution of the pest population should be monitored and the mulch practice limited if contra productive. Last but not least, trees should be cut carefully and wounds healed to avoid entry of the termites.

Nematodes and soil-borne diseases: At the end of each rotation cycle, mustard is sown. After 2 months (flowering, before earing) they should be cut and their flowers incorporated in the soil. Their decomposition secrete molecules that will kill some nematodes and soil-borne diseases.

Birds and mammals: Traps for rodents are positioned around the cereal plots. At hearing of cereals, scarecrows are displayed to scare off birds. An increased vigilance is essential when the grains mature and they should be harvested as soon as possible.

Treatment in case of infection

Insect traps: In case of high pest pressure, insect traps are positioned next to the infected crops. They can be pet bottles filled with crushed banana or papaya and water, or sticky traps using crashed banana or papaya on carton. Pheromone traps can furthermore be used.

Insect repelling mixtures: In case of high pest pressure, natural macerations are sprayed 2-3 times a week. Use 3 times a treatment before trying another one. If the treatment has no effect, change directly to another.

Garlic maceration: Crush garlic cloves. Mix 2 tablespoons of garlic powder with 10 l water. Leave it macerate for 12 h. Mix 1 L of the product with 2 l of soapy water (3 soap lids + 4 l water). Spray 1 l on 10 m^2 of crop. To use against aphids, mites and flies.

Chili maceration: Same as garlic with crushed chilis. To use against biting and sucking insects, caterpillars, crickets.

Tomato maceration: Crush and macerate 200 g tomato leaves in 1 l water for 12 h. Filter and add 1 ml soap. Spray 3 l per m^2. To use against various insects and fungi.

Papaya maceration: Crush 1 kg of papaya leaves and mix it with 10 l water. Add a little clay, close the recipient allowing air to come in. Let it fermentate for 15 days and filtrate. Spray 1 l per 10 m^2. To use against fungis (powdery mildew and rust).

Marigold maceration: Macerate marigold flowers and leaves. To use mainly against white flies, moths and leafhoppers.

Neem leaves maceration: 3 kg crushed neem leaves + 10 l water + 30 ml soap, macerate 24 h. Filtrate and spray on leaves. The leave residues are applied on the soil as fertilizer and nematicide.

Neem oil: Crush 2.5 kg of neem oil. Macerate 12h in 10 l water and filtrate. Mix with 5 l of soapy water and spray. To use against insects if the other treatments fail. Possible to purchase neem oil directly.

Neem powder: Grind neem bark and seeds, mix with water and infuse for 1 day. Add soap and then apply 2 l per tree foot or per m^2. Use against soil pests such as termites, especially to protect young trees and vegetables.

Milk: Mix 50% milk with 50% water to treat infected plants, 20% milk with 80% water for the surrounding plants as prevention.

Fern : 3 kg of ferns in 10 l water, macerate 24h. Dillute at 10%. Against stemborers

Ashes: 1 kg in 10 l, filtrate and add 20 l of water. Against stemborers and leaves feeders.

Tobaco: macerate 1 kg of leaves in 10 l for 24h. Filtrate and dillute at 10%.

Cocktail: It is also possible to combine the different ingredients to have a wider effect. For example, 1 kilo of each ingredient garlic ginger pepper leaves of neem or crushed papaya to macerate in 20 l for a week. Add soap. Water or spray 1 l of the product in 15 l of water.

8. Detailed description

8.1. Zone I– Vegetable and tuber production

Plot separation

The separation between the plots is done with a double row of pineapple. The distance between the rows is 1 m, the distance on the line is 30 cm. Pineapples help limit erosion and produce fruits. The space between the rows serves as a path. Pineapples must be planted regularly to allow continuous fruit production.

Nurseries

The seedlings are prepared in rustic nurseries, built with stakes of 0.5 m – 1 m high to install mosquito nets to protect the crops. The size of the structures depends on the size of the nets. A stony cord is built around the structure to prevent the entry of rodents. Sowing is done in prepared beds by mixing soil (70%) with manure (30%). Nurseries are located in the built-up area. Seedlings are constantly sown, raised and transplanted, so that the production of the various vegetables is spread over a long period of time. Direct sowing and transplantation are done at the same time. Seedlings must therefore be initiated enough time before the start of the field. IF available, seedlings are prepared in trays in a greenhouse.

Figure 6 : Example of a seedling nursery.

8.1.1. Subzone I.I : vegetable production

Plot preparation

The plot of subzone I.I are superficially ploughed by hand every year (10 cm depth). Raised beds of 10 to 30 cm high and 1 m wide are created. The beds cross the whole plot in length. Drip irrigation is installed with 30 cm spacing, and three pipes per raised bed. Base fertilisation is applied on the raised beds before planting. Additional fertilizer are applied at the feet of the crops. In the dry season, vegetables are transplanted in small zai holes dug in the raised beds. The manure and the water is thus concentrated in these holes. The plots inside the greenhouses are prepared the same way.

Fertilisation and nutrient demand

Table 3 : Quantity of manure to apply for each crop in subzone I.I. The amount is given in kg / plot and in g/m-lin on the line. The first value is used to know the quantity needed for the plot, the second is used during the application. Crops not presented here are not fertilized specifically.

		Manure Input per plot [kg]				Manure input on the lign [g/m-lin]				
Crop		Ruminant	Chicken			Ruminant	Chicken			
		Plantation	Flowering	Fructification	1st harvest	Plantation	Flowering	Fructification	1st harvest	Total
1.1	Chard	383	0	0	0	170	0	0	0	**170**
1.1	Cauliflower	337	104	0	0	299	92	0	0	**392**
1.2, 3.1	Maize	368	0	66	0	408	0	74	0	**482**
1.2	Pumpkin	121	19	19	0	204	32	32	0	**267**
1.3	Beetroot	253	0	0	0	170	0	0	0	**170**
1.3	Carrot	231	0	0	0	156	0	0	0	**156**
1.3	Onion	282	0	0	0	190	0	0	0	**190**
2.2	Pepper	374	81	135	54	208	45	75	30	**357**
3.1, GH	Watermelon	255	39	39	0	255	39	39	0	**334**
3.2, GH	Cabbage	225	69	0	0	299	92	0	0	**392**
3.2, GH	Cucumber	168	26	26	0	255	39	39	0	**334**
3.2, GH	Lettuce	183	0	0	0	167	0	0	0	**167**
4.1, GH	Tomato	474	102	171	68	237	51	85	34	**408**
	Total	**4021**	**440**	**522**	**122**					

Crop duration and care, spacing and seeds information

Table 4 : Cultivation information for the different crops in subzone I.I. Crops colored together are associated. The usable plot size is the plot without ways. Soil preparation is indicated as follows: RB = Raised Beds, R (x;y) = Ridges (Distance between ridges,height), M (x,y) = Mounds, none = seeding/transplantation is done in the field as it is after the preceding crop. Seeding type is indicated as follows: SH(x,y) = Seedhole (seeds per hole, plant number to clear to), TP = Transplantation, L = Line seeding, BS = Broadcast Seeding.

Specie			Crop duration [weeks]			Weeding	Soil prep	Seed				Seedling	Spacing [cm]		Density
Name	Family	Rot. Break	Nursery	Unprod.	Prod	[WAP]		Type	Depth [cm]	[kg/ha]	per plot [g]	Number	On line	Between rov	[plant/ha]
Beetroot	Chenopodiac	4/7	3	3	6	Each 2	RB	TP	1	6	378	7 000	50	50	111 111
Cauliflower	Brassicaceae	4/7	3	4	2	Each 2	RB	TP	1	0,3	19	2 520	50	50	40 000
Maize	Poaceae	3/5	0	9-13	1	3,5,7	None	SH(2-1)	3-4	25	2250	0	40	100	25 000
Greenbean	Fabaceae	3/4	0	4-5	3-4	3,5,7	None	SH(1-1)	1-2	7	630	0	20	100	50 000
Pumpkin	Cucurbitacea	5/7	2	4-5	2-3	3,5,7	None	TP	1-2	1,2	108	360	250	100	4 000
Carrot	Apiaceae	4/7	0	12	3-4	Each 2	RB	L	0.5	2	126	0	3	60	555 556
Onion/Garli	Alliaceae	5/7	4	10	2	Each 2	RB	TP	0.5	2	126	10 500	10	60	166 667
Beetroot	Chenopodiac	4/7	3	12	2	Each 2	RB	TP	1	6	378	7 000	15	60	111 111
Mustard	Brassicaceae		0	6-8	0	0	None	BS	0	20	1800	0	-	-	-	
Pepper	Solanaceae	4/7	3	8	6	Each 2	RB	TP	1-2	0,25	16	2 520	50	50	40 000
Aromatic he	Different		3	4	2-3	Each 2	RB	TP	0.5-1	0,25	16	2 520	50	50	40 000
Maize	Poaceae	3/5	0	9-13	1	3,5,7	None	SH(2-1)	3-4	25	2250	0	40	100	25 000
Horsebean	Fabaceae	3/4	0	4-5	3-4	3,5,7	None	SH(1-1)	1-2	7	630	0	20	100	50 000
Watermelon	Cucurbitacea	5/7	3	4-5	2-3	3,5,7	None	TP	1-2	1,2	108	360	250	100	4 000
Lettuce	Asteraceae	4/7	3	6	2	Each 2	RB	TP	0.5	0,3	19	5 250	20	60	83 333
Cabbage	Brassicaceae	4/7	3	10	2	Each 2	RB	TP	1	0,3	19	2 625	40	60	41 667
Cucumber	Cucurbitacea	5/7	3	4-5	4-5	Each 2	RB	TP	1-2	0,4	25	3 938	40	40	62 500
Mucuna	Fabaceae		0	10	2	3,5,7	None	SH (1-1)	2	20	1800	0	30	30	111 111
Tomato	Solanaceae	4/7	3	8	6	Each 2	RB	TP	1-2	0,25	16	1 575	80	50	25 000
Marygold	Asteraceae	4/7	3	4	2-3	Each 2	RB	SH (2-1)	0.5-1	0,4	25	0	80	50	25 000

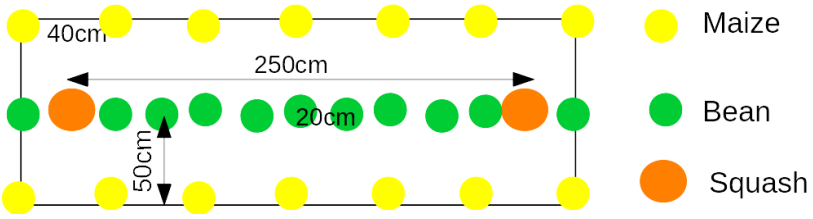
Table 5 : Cultivation information for the different crops in the greenhouses of subzone I.I. Crops colored together are associated. Soil preparation is indicated as follows: RB = Raised Beds, R (x;y) = Ridges (Distance between ridges,height), M (x,y) = Mounds, none = seeding/transplantation is done in the field as it is after the preceding crop. Seeding type is indicated as follows: SH(x,y) = Seedhole (seeds per hole, plant number to clear to), TP = Transplantation, L = Line seeding, BS = Broadcast Seeding.

Specie			Crop duration [weeks]			Weeding	Soil prep	Seed				Seedling	Spacing [cm]		Density
Name	Family	Rot. Break	Nursery	Unprod.	Prod	[WAP]		Type	Depth [cm]	[kg/ha]	per plot [g]	Number	On line	Between rov	[plant/ha]
Tomato	Solanaceae	4/7	3	8	12	Each 2	RB	TP	1-2	0,25	4	350	80	50	25 000
Marygold	Asteraceae	4/7	3	4	2-3	Each 2	RB	SH (2-1)	0.5-1	0,4	6	0	80	50	25 000
Lettuce	Asteraceae	4/7	3	6	2	Each 2	RB	TP	0.5	0,3	4	1 167	20	60	83 333
Cabbage	Brassicaceae	4/7	3	10	2	Each 2	RB	TP	1	0,3	4	583	40	60	41 667
Cucumber	Cucurbitacea	5/7	3	4-5	4-5	Each 2	RB	TP	1-2	0,4	6	560	50	50	40 000
Tomato	Solanaceae	4/7	3	8	6	Each 2	RB	TP	1-2	0,25	4	350	80	50	25 000
Aromatic he	Different		3	4	2-3	Each 2	RB	TP	0.5-1	0,25	4	560	50	50	40 000
Watermelon	Cucurbitacea	5/7	0	6-7	2-3	3,5,7	None	SH (2-1)	1-2	2,5	50	0	100	100	10 000
Mustard	Brassicaceae		0	6-8	0	0	None	BS	0	20	400	0	-	-	-

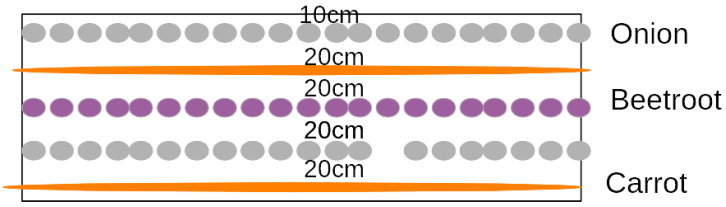
Planting scheme

All crop association scheme are presented here. When only one crop is cultivated, it is assumed that the information on spacing is sufficient.

Crops 1.2 and 3.1 : Maize, Bean, Squash or Melon



Crops 1.3: Carrot, Onion and Beetroot

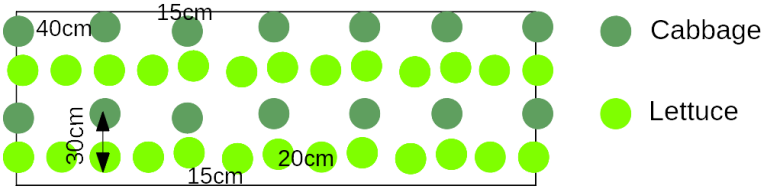


Crops 2.1 and GH4.2 : Mustard

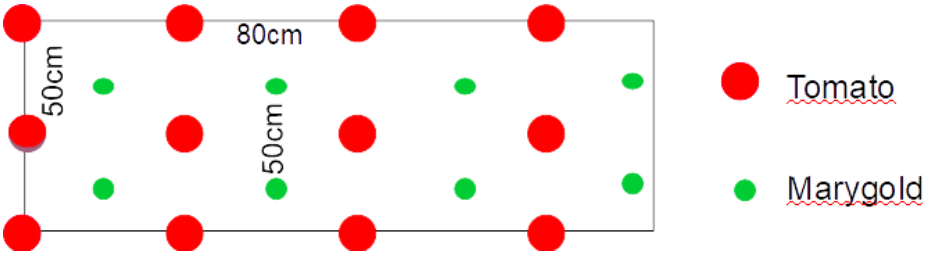
Mustard is broadcast sown. At flowering (after 2 months), it is cut and directly incorporated in the soil (max 5 minutes) in order to allow biofumigation (killing of soilborne diseases, nematodes and pests). It is important to cut it before hearing in order to prevent invasivity of mustard.

Crops 3.2 and GH2.1 : Cabbage, Lettuce and Cucumber

Alternate one raised bed of cucumber with two of Cabbage and Lettuce associated. Plant different cabbages (Kale, cabbage etc.) on different beds.



Crops 4.2 and GH1.1 and 3.1 : Tomato and marygold/aromatic herbs



8.1.2. Subzone I.II: Semi-agroforestry

Installation of perennial plants: plantain, banana, papaya, pigeon pea

The perenials are planted in June with a spacing of 4 m x 4 m alternating fruit trees (papayas, bananas) with pigeon pea. On the whole area, it is planned to plant 24 papaya, 24 bananas or plantains and 24 pigeon peas. Papaya is raised in the nursery before being transplanted. Banana are planted by rhizomes in 50 cm deep holes. Pigeon pea is sown directly (2 grains per poquet). Pigeon pea should be pruned to 2-4 m to limit shade on annuals. Fruits are harvested when ripe, banana must be cut at that time and one or two ratoons left to regrow.

Plot preparation

The plots of subzone I.II are superficially ploughed by hand every year (10 cm depth). Ridges or mounds are then created. For potatoes, 30 cm high ridges are built with a distance of 40 cm between the ridges. For sweet potato, the ridges are 40 cm high and 70 cm apart. For yam, mounds of 50 cm are built at a spacing of 1m x 1m. For stylosanthes, no specific soil preparation is done.

Fertilisation and nutrient demand

Table 6 : Quantity of manure to apply for each crop in subzone I.II. The amount is given in kg / plot and in g/m-lin on the line. The first value is used to know the quantity needed for the plot, the second is used during the application. Crops not presented here are not fertilized specifically.

		Manure Input per plot [kg]				Manure input on the lign [g/m-lin]				
Crop		Ruminant	Chicken			Ruminant	Chicken			
		Plantation	Flowering	Fructification	1st harvest	Plantation	Flowering	Fructification	1st harvest	Total
1.1	Maize	441	0	79	0	408	0	74	0	**482**
1.2	Potato	710	0	219	73	316	0	97	32	**445**
4.1	Pumpkin	147	23	23	0	204	32	32	0	**267**
4.1	Ginger/Curcuma	672	0	121	0	280	0	50	0	**330**
Perrenials	Banana/Papaya	563	0	0	0	0	0	0	0	**0**
	Total	**2532**	**23**	**442**	**73**					

Crop duration and care, spacing and seeds information

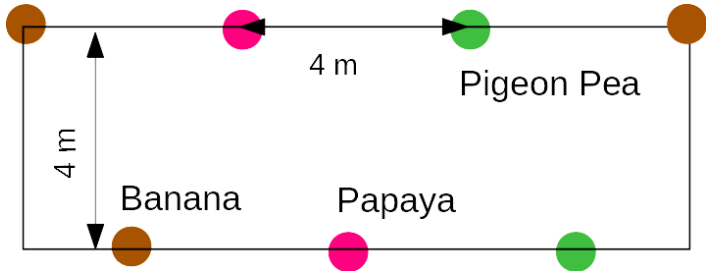
Table 7 : Cultivation information for the different crops in subzone I.II. Crops colored together are associated. Soil preparation is indicated as follows: RB = Raised Beds, R (x;y) = Ridges (Distance between ridges,height), M (x,y) = Mounds, none = seeding/transplantation is done in the field as it is after the preceding crop. Seeding type is indicated as follows: SH(x,y) = Seedhole (seeds per hole, plant number to clear to), TP = Transplantation, L = Line seeding, BS = Broadcast Seeding, C = Cutting seed, T = Tuber seed.

Specie			Crop duration [weeks]			Weeding	Soil prep	Seed				Seedling	Spacing [cm]		Density
Name	Family	Rot. Break	Nursery	Unprod.	Prod	[WAP]		Type	Depth [cm]	[kg/ha]	per plot [g]	Number	On line	Between rov	[plant/ha]
Banana/Plan	Musa		0	40	8	None	None	H	40	-	-	24	1200	1200	69
Papaya	Carica.		8	40	150-200	None	None	H	30	-	-	24	1200	1200	69
Pigeon Pea	Legume		0	24	150-200	None	None	SH(2-1)	2-3	-	-	24	1200	1200	69
Maize	Poaceae	3/5	0	9-13	1	3,5,7	None	SH(2-1)	3-4	25	2250	0	40	100	25 000
Pea	Fabaceae	3/4	0	4-5	2-3	3,5,7	None	SH(1-1)	1-2	70	6300	0	5	100	200 000
Potato	Solan.	4/7	0	5-7	2	3,5,7	R(40,30)	SH(1-1)	10	1 500	135 000	0	30	40	83 333
Sweet potat	Convov.		0	16-24	4-12	2	R(70,40)	C	-	-	-	3 214	40	70	35 714
Stylosanthes	Legume	1/2	0	24	24	3,5,7	None	BS	0	6	540	0	-	-	-
Curcuma/gin	Zingiber.	3/4	0	28	3-4	3,5,12,18	M(100,50)	T	30	200	18 000	900	100	100	10 000
Squash	Cucurbit.	5/7	2	4-5	2-3	3,5	None	TP	1-2	1	108	900	100	100	10 000

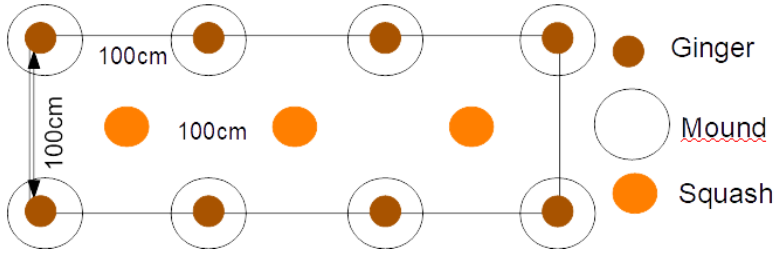
Planting scheme

All crop association scheme are presented here. When only one crop is cultivated, it is assumed that the information on spacing is sufficient.

Perennials : Banana/Plantain, Papaya and Pigeon Pea



Crop 4.1 : Ginger/curcuma and Pumpkin



8.2. Zone II : Cropland production

Installation of napier grass or pennisetum

As explained in the chapter "Pest and Disease Control", brachiaria or napier grass is used to attract grain pests outside the main crop. A double row is sown between the plots, a single row at the foot of the hedges on the sides of the plots. The distance on the line is 40 cm. Sow either several seeds or one cutting per seedhole. The first lines of cereal should start at least 1 m from the grass.

Plot preparation

Except in the first year where the whole zone is ploughed, direct seeding is practiced in this zone, as explained in chapter “Soil management”. The zone must remained covered by mulch in the dry season. Soil loosening can be done using subsoilers or broadforks.

Fertilisation and nutrient demand

Table 8 : Quantity of manure to apply for each crop in zone II. The amount is given in kg / plot and in t/ha. Crops not presented here are not fertilized specifically.

		Manure input [t/ha]		Manure input per plot [kg]	
Crop		Ruminant	Chicken	Ruminant	Chicken
		Plantation	Earing	Plantation	Earing
1.1	Maïs	8.2	1.5	1633	294
1.2	Sorgo	6.2	1.1	1233	222
3.1	Bissap	5.2	1.6	1034	319
4.1	Blé	7.3	1.3	1452	261
5.2	Oat	6.5	0.0	1303	0
0	**Total besoin**	**5.5**	**0.9**	**6656**	**1097**

Crop duration, care, spacing and seeds

Table 9 : Cultivation information for the different crops in zone II. Crops colored together are associated. Soil preparation is indicated as follows: SL = Soil loosening using broadforks or subsoilers, none = seeding is done in the field as it is after the preceding crop. Seeding type is indicated as follows: SH(x,y) = Seedhole (seeds per hole, plant number to clear to), L = Line seeding, BS = Broadcast Seeding.

Crop	Specie	Family	Rot. Break	Crop duration [W]	Weeding [WAP]	Soil prep	Seed Type	Depth [cm]	Rate [kg/ha]	per plot [kg]	Spacing [cm] On line	Spacing [cm] Interrows	Density [plant/ha]
1.1	**Maize**	Grass	1/2	12-16	3,5,7	SL	SH	3-4	30	6	40	75	33 333
1.2	**Sorgo**	Grass	1/2	12-16	3,5,7	SL	SH	4-5	15	3	40	75	33 333
1.1	**Desmodium**	Legume	3/5	96	3,5,7	SL	L	1-2	5	1	2	75	666 667
3.1	**Bissap**	Malva.		16	3,5,9	SL	SH(2-1)	2-3	5	1	40	80	111 111
3.2	**Mustard**	Brassic.	4/7	6-8	None	None	BS	0	20	4	-	-	-
4.1	**Wheat**	Grass	1/2	10-12	3,5,9	SL	L	2-4	200	40	10	25	400 000
4.2	**Cowpea**	Legume	1/2	8-10	3.5	None	P(1-1)	2-3	22	4	50	15	500 000
5.1	**Faba Bean**	Legume	1/2	10-12	3,5,9	SL	SH(1-1)	4-6	150	30	20	20	250 000
5.2	**Oat**	Grass	3/4	10-12	None	SL	BS	0	40	8	-	-	-
6.1, 6.2	**Soybean**	Legume	3/4	8-10	3,5,9	SL	SH(1-1)	2-4	100	20	15	15	444 444

8.4. Zone II – Pasture production

It is estimated that the system can sustain 9 milkcows, 8 heifers, 566 chicken broilers, 38 laying hens, 10 ducks and 600 fish. This estimate is approximate and the number must be adapted after the first few years. The area for animals (18,000 m^2) is composed of a barn of 200 m^2 with around a permanent exit area of 800 m^2, as well as a grazing area of 16,000 m^2 with pigeon pea hedges of 1000 m^2. A barbed wire fence is established all around the area to prevent the animals from wandering in the other zones of the farm.

Housing of animals: The ruminant barn must provide shade and protection from the rain. A wall of 1 m height is sufficient to stop the animals from getting out. The zone where the feed is given should only allow the animals to access with their heads, in order to avoid having manure on the feed. An access to clean water is essential as well. The chicken barn must be closed with a fence (between the wall and the roof) to avoid poultry getting out or animals getting in. The poultry barn must have separation to separate the broilers of different age and size, as well as the laying hens. The laying hens must have perch and nesting boxes. The floor of both barns must be concrete to allow good hygiene and easy collection of the manure. Both barns must have an access to permanent pasture.

Table 10 : Number of animals, outdoor and indoor space needed for the different animals of the farm.

Animals	Number of animals	Indoor space / head [m2]	Outdoor space / head [m2]	Total indoor space [m2]	Total outdoor space [m2]
Cows	9	3	5	27	45
Veals	8	1	2	8	16
Hens	38	0.25	0.5	10	19
Broilers	Capacity of 800	0.05	0.1	41	83
Indian Runner Ducks	10	0.25	0.5	2.5	5

Installation of animals: Initially, 6 milk cows are purchased. Allow the herds to reproduce until they reach the desired population, taking care to have enough fodder to support them. Chicken broilers are bought (200 at a time, 800 maximum) from outside and raised on the farm. 30 hens and 5 ducks are bought and allow to reproduce until reaching sufficient size.

Production: Fertilization of the milkcows is done by artificial insemination. Sick or newly given birth cows are separated from the herd (in an isolation pen at night) to protect them and limit contamination. Heifer are raised to increase herd size, eventually sold after maximum 3 years, while male are sold at 6 months. Animals that are unhealthy or over the age of 5 years can be replaced by more robust young.

Chickens are used for meat production. Batch of 200 broilers are regularly bought, raised and sold when 50 days old. The maximum capacity is 800 broilers.

Hens and ducks are used for egg production. Keep 3 to 5 roosters for reproduction.

Grazing area: Three pigeon pea hedges are sown to separate the grazing area into 4 fields of 4000 m^2. The hedges are placed so that the animals have access to the barn from each field. The pigeon pea is sown at a distance of 20 cm on the line. Animals should not be introduced until the hedge is large enough. It will prevent wandering between plots and provide additional fodder. Fertilization is not done in this zone, only through direct animal excretion.

We start by ploughing the 4 fields, then we broadcast sow a mixture of fodder. The mixture must be balanced between legume and grasses. Table 11 summarize the species that can be sown with the according rates. Use 5 different grasses and 5 different legumes in the mixture at the minimum.

Table 11 : list of possible fodder crops for zone III. The sowing rate in purestand is indicated in [kg/ha] or [cuttings/ha], as well as the rate in a mixture with 5 grass species and 5 legume species. The quantity for the whole zone III is furthermore given. If less or more species are used, the calculation should be remade based on the purestand value.

Family	Common N.	Botanical N.	[Unit]	Purestand [/ha]	Mixture [/ha]	Quantity needed
Gass	Rhodes grass	*Chloris gayana*	kg	8	1.6	2.6
Grass	Andropogon	*Andropogon gayanus*	cut.	10000	2000	3200
Grass	Brachiaria	*B. ruziziensis*	kg	8	1.6	2.6
Grass	Dasho grass	*Pennisetum pedicelatum*	cut.	10000	2000	3200
Grass	Napier/Elephant	*Pennisetum purpureum*	cut.	10000	2000	3200
Grass	Oat	*Avena sativa*	kg	20	4	6.4
Grass	Panicum	*Panicum maximum*	cut.	10000	2000	3200
Grass	Pennisetum	*Pennisetum ruziziensis*	cut.	10000	2000	3200
Grass	Sorgho	*Sorghum bicolor*	kg	8	1.6	2.6
Legume	Alfafa	*Medicago sativa*	kg	8	1.6	2.6
Legume	Alizicarpus	*Alizicarpus ovalifolia*	kg	6	1.2	1.9
Legume	Cassia	*Chamaechrista rotundifolia*	kg	1	0.2	0.3
Legume	Cowpea	*Vigna unguiculata*	kg	10	2	3.2
Legume	Crotalaria	*C. juncea*	kg	4	0.8	1.28
Legume	Desmodium	*D. intortum, D. uncinatum*	kg	2	0.4	0.6
Legume	Lablab bean	*Lablab purpureus*	kg	15	3	4.8
Legume	Mucuna	*Mucuna pruriens*	kg	40	8	12.8
Legume	Perennial soybean	*Neonotonia wightii*	kg	2	0.4	0.6
Legume	Pigeon pea	*Cajanus cajan*	kg	16	3.2	5.1
Legume	Stylosanthes	*S. guianensis, S. hamata*	kg	6	1.2	1.9
Legume	Vetch	*Vicia vilosa*	kg	80	16	25.6

Trees are planted to provide shade for animals in the permanent exit area. Young trees must be protected from animals before reaching sufficient size.

Animals begin to graze on one of the plots. Once everything has been grazed, the animals are sent to the next plot. The first plot is left without pasture until the vegetation has grown back. Animals should not be sent to a plot whose vegetation has not fully regrown. Animals should not be left on the same plot for too long to prevent them from killing plants, especially in the dry season. If no plot is suitable at a certain time, the animals are left in the pen and fed with cut and carry fodder. Animals should be left long enough to avoid selective consumption of species leading to grass problems and poor grassland quality. A small zone is protected for seed production. After 3-4 years, legumes are reseeded without tillage. Animals can also pasture in zone IV, once the trees are big enough.

Chicken and hens stay most of the time in their barn and permanent outside access. Ducks are allowed to pasture everywhere at all time. Indian runner ducks do not cause harm to crops, fight pests and fertilize.

Using of animals for soil preparation : Cows are mainly located in their barn and its permanent outside exit, as well as alternating between the 4 fields of the pasture zone, and eventually in zone IV. Poultry stay in the barn and in the permanent outside access. When a plot of zones I or II is left fallow, cows can graze there. A few weeks before sowing a crop, animals can be sent to any plot to deworm, weed, fertilize and loosen the soil. As a result, they feed on the remains of the previous crop or green manure. In case of pest invasion, poultry are sent to the infected plot, but should be kept under surveillance as they can damage the crops.

Nutrition: In addition to the pasture mentioned above, fodder is produced by the system. Kitchen waste is given to poultry and the production of straw and leaves (gliricidia, sesbania, pigeon pea, mucuna, sweet potato, cereals, desmodium, brachiaria and beans) to cows. Part of it must be dried into hay to feed the animals in the dry season. The fruits of moringa, legume trees and pigeon peas are given as energy and protein supplements. A corn supplement is possible. For ruminants, the intake of roughage is done twice a day, the protein intake only in the morning. When cows do not have access to grazing surfaces, roughage should be given to them all day through cut and carry. Poultry are fed twice a day with legume fruits and maize. Ducks obtain their main calory intake by hunting insects.

Health: Hardy breed animals adapted to the local climate are used. Sick animals and tired non-bearing females are isolated, especially before and after giving birth. Acacia fodder (ideally A. raddiana, A. nilotica and A. karoo) and moringa (leaves and seeds) help fight gastric parasites (helminths, nematodes) of ruminants. Fly traps are installed in the barn.

8.5. Zone IV : agroforestry

The Trees of different size and shape are planted to optimize space and shading. At the beginning, the trees must be protected from the animals, but when they are big enough, the zone can be used as a pasture. Once the system is implemented, a subcover of mucuna is planted and stays indefinitely as ground cover and pasture.

Fertilisation

Coffe and fruit trees are fertilized once a year, with a mix of 50% chicken manure and 50% ruminant manure.

Table 12 : fertilisation need of the trees in zone IV.

	Manure per tree [kg]	**Number of trees**	**Manure to apply (Total)**
Coffee	1.5	6000	9000
Fruit trees	1.0	4000	4000

Irrigation

Coffee and fruit trees are watered on a regular basis using a trolley during the dry season.

7.4.1 Subzone IV.I : Coffee + shade trees

Coffee is planted at a density of 2 m x 2 m under an existing forest. If forest it not here, or if trees need to be replace, shade tree can be cleared or planted at a density of 2 to 20 m, according to the tree species. Possible shade trees are listed below.

7.4.2 Subzone IV.II : Coffee + fruit +shade trees

Coffee is planted at a density of 2 m x 4 m under an existing forest. If forest it not here, or if trees need to be replaced, the shade tree species listed below can be used. Banana, papaya and ananas are planted at a density of 2 m x 4 m between the coffee rows. Every 12 m, an avocado tree is planted instead.

The following pattern is therefore to be established in this subzone:

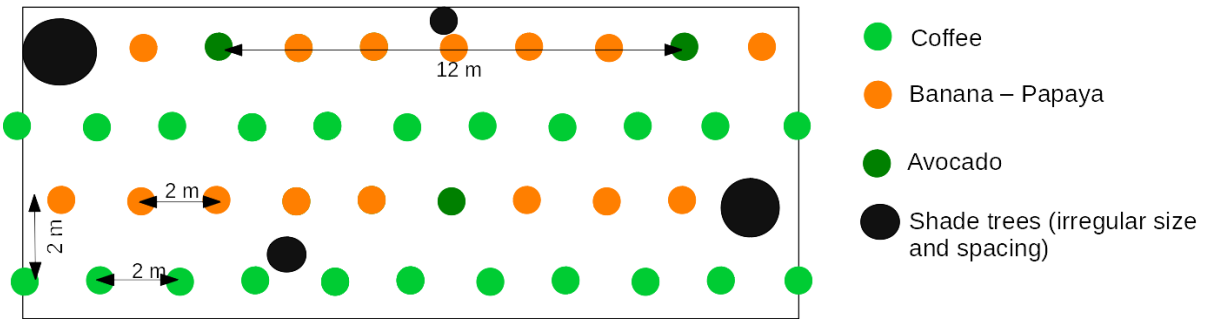


Figure 7 : pattern of tree disposition in subzone IV.II.

7.4.3 Subzone IV.III : Coffee + fruit trees

Coffee is planted at a density of 2 m x 4 m on open land. If forest it not here, or if trees need to be replaced, the shade tree species listed below can be used. Banana, papaya and ananas are planted at a density of 2 m x 4 m between the coffe rows. Every 12 m, an avocado tree is planted instead.

The following pattern is therefore to be established in this subzone:

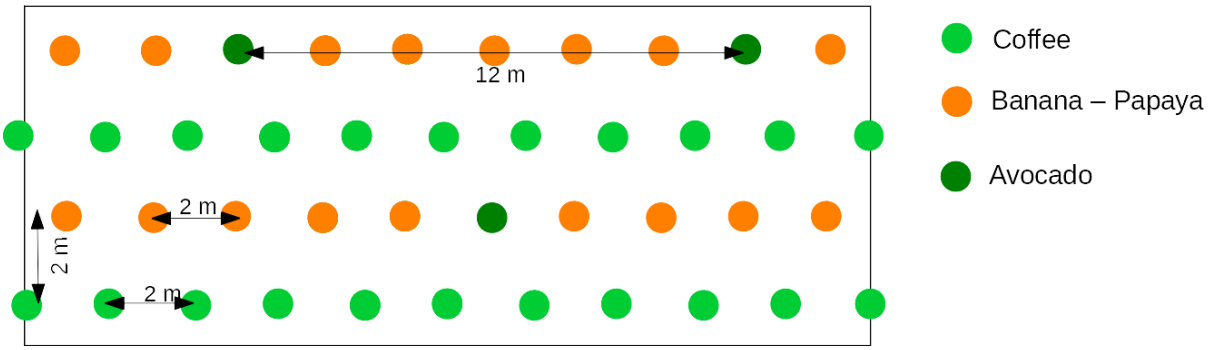


Figure 8 : pattern of tree disposition in subzone IV.III.

Species of coffee, legume, shade, citrus and big fruit trees

The tree species of the agroforestery system can be chosen in the list below. Try being the more diverse as possible. Ideally, use all trees listed below, specially for the legume and fruit trees.

Table 13 : List of fruit trees, legumes trees and shade trees. The common name, the local name and the botanic name is given, as well as the potential use. The size of the tree is given following this scale: S = Schrub < 5 m high, ST = Small Tree 5-10 m, T = Tree 10-15 m, LT = Large Tree 15-20 m, HT = Huge Tree > 20 m. The use of the tree is indicated as follow: Fr = Fruit, Fo = Fodder, Fu = Fuel, Fe = Fertilizing, M = Medicinal, S = Shade, T = Timber, P = Phytosanitary, L = Leaves

Category	Common N.	Local N.	Botanic N.	Use	Size
Fruit	Ananas		*Ananas comosus*	Fr	S
Fruit	Papaya		*Carica papaya*	Fr, P	ST
Fruit	Avocado		*Persea americana*	Fr	T
Fruit	Banana		*Musa*	Fr	ST
Legume			*Acacia albida*	Fe Fo M S	T
Legume			*Acacia nilotica*	Fe Fo M S	ST
Legume			*Acacia seyal*	Fe Fo M S	ST
Legume	Pigeon pea		*Cajanus cajan*	Fe Fo	S
Legume			*Calliandra calothyrsus*	Fe Fo Fu S	S
Legume			*Gliricidia sepium*	Fe Fo S	ST
Legume			*Leucaena diversifolia*	Fe Fo Fu S	ST
Legume			*Prosopis glandulosa*	Fe Fo	S
Legume			*Sesbania sesban*	Fe Fo Fu S	S
Shade		Lafto	*Acacia abyssinica*	Fe S	T
Shade	Peacock flower	Sesa, Ambabessa	*Albizia gummifera*	Fe S	HT
Shade		Ambabessa, Chatto	*Albizia schimperiana*	Fe S	HT
Shade	Winged bersama	Lolchissa	*Bersama abyssinica*	T M S	T
Shade	Flame tree	Enka, Wolensu	*B. acerifolius*	S	LT
Shade		Komogno	*Brucea antidysenterica*	M T Fu S	ST
Shade		Cheka	*Calpurnia aurea benth*	Fe M Fo S	S
Shade	White sapote	Kazamora, Kazmir	*Casimiroa edulis*	Fr M S	T
Shade	Kapok tree	Yetit zaf	*Ceiba pentandra*	M S	HT

Shade	White stinkwood	Kayee	*Celtis africana*	T S	T
Shade		Ulmayee, Limch	*Clausena anisata*	Fr M S	ST
Shade		Wadessa	*Cordia africana*	Fr T M S	T
Shade		Makanissa, Bakannisa	*Croton macrostachyus*	M T S	LT
Shade	Giant Diospyros	Lokko	*Diospyros abyssinica*	T S	LT
Shade		Danissa	*Dombeya torrida*	T Fu S	T
Shade	Dragon tree	Lankuso, Showiye	*Dracaena draco*	M S	T
Shade		Hulaga	*Ehretia cymosa*	M L S	ST
Shade		Duduna, Sombo	*Ekebergia capensis*	M S	T
Shade		Walensu, Addi	*Erythrina abyssinica*	Fe S	T
Shade	Rubber tree	Yegoma zaf	*Ficus elastica*	S	LT
Shade		Habru	*Ficus sur*	M Fr S	T
Shade	Sycamore fig	Harbu	*Ficus sycomorus*	Fr S	LT
Shade	Leucaena	Lukina, Tininsh sesa	*Leucaena leucocephala*	Fe Fo Fu S	ST
Shade	Nile Tulip	Buturu	*Markhamia lutea*	Fu T M S	ST
Shade		Kombolcha	*Maytenus arbutifolia*	S	ST
Shade		Askira, Birbira	*Millettia ferruginea*	Fe T S	HT
Shade	African wild olive	Ejerssa ,Wira	*Olea europaea*	T Fr S	ST
Shade	Elgon teak		*Olea welwitschii*	T S	HT
Shade	Snuff-box tree	Akukku	*Oncoba spinosa*	Fr Fu M S	S
Shade		Mito	*Oxyanthus speciosus*	Fu S	T
Shade	Wild date palm	Selen, Zembaba,mexi	*Phoenix sylvestris*	M S	T
Shade		Karrio, Yezinjero wonber	*Polyscias fulva*	T S	HT
Shade		Baya	*Pouteria adolfi-riederici*	T S	HT
Shade		Hadad, Hurgessa, Urgessa	*Premna schimperi*	S	S
Shade	African cherry	Hoomii	*Prunus africana*	T M S	HT
Shade	Guava	Zeituna	*Psidium guajava*	Fr M Fu S	ST
Shade		Bossoqa	*Sapium ellipticum*	Fu S	T
Shade	Sesbania	Enchini, Harcha	*Sesbania sesban*	Fe Fo Fu S	ST
Shade	African tulip tree		*Spathodea*	M T S	LT
Shade		Hadesa	*Strychnos henningsii*	M T S	ST
Shade	Natal orange	Merenz	*Strychnos spinosa*	M S	T
Shade		Badessa	*Syzygium guineense*	L S	T
Shade	Forest mahogany	Konu, Luya, Shego lolichsa	*Trichilia dregeana*	Fr M T Fu S	HT
Shade	Natal mahogany	Cape mahogany, sombo	*Trichilia emetica*	M T Fu S	LT
Shade		Rejji	*Vernonia amygdalina*	L S	S

8.6. Zone V : building compound

This zone contains buildings and infrastructures needed by the other zones. Furthermore, it specifically contains a fish pound.

Neem trees must be planted in this zone to make shade and to have a source for biopesticide.

Fish pound

A fish pond of 10 m x 20 m x 1 m is built, which can have around 600 fish. The pond is dug in the ground to have sufficient aeration (no concrete). Tilapia and catfishes are raised. Composted chicken manure (around 5 t / year) is fed to the fish. The water is changed every week and used for fertirrigation of the vegetables.

8.7. Live Productive hedges

Hedges are mainly composed of fodder, medicinal and drought tolerant trees. They are planted on a line surrounding the whole farm. Trees are planted 50 cm apart, so there should be 2000 trees in total. Regular weeding and watering is essential the first year only. The shrubs are trimmed twice a year at a height of 1.5-2m. The harvested leaves are used as fodder, while the woody waste is transformed in biochar. We alternate the species according to their height. On the outer rim, a stone barrier is dug to prevent erosion, and a fence can be build to protect the agroecosystem at the beginning. The table below summarize the species that can be planted. Ideally, plant trees of all listed species.

Table 14 : List of potential trees for unirrigated live hedges. The common name, the local name and the botanic name is given, as well as the potential use. The size of the tree is given following this scale: S = Schrub < 5 m high, ST = Small Tree 5-10 m, T = Tree 10-15 m, LT = Large Tree 15-20 m, HT = Huge Tree > 20 m. The use of the tree is indicated as follow: Fr = Fruit, Fo = Fodder, Fu = Fuel, Fe = Fertilizing, M = Medicinal, S = Shade, T = Timber, P = Phytosanitary, L = Leaves

Category	Common N.	Local N.	Botanic N.	Use	Size
Fruit	Cashew tree		*Anacardium occidentale*	Fr	ST
Legume			*Acacia albida*	Fe Fo M S	T
Legume			*Acacia nilotica*	Fe Fo M S	ST
Legume			*Acacia seyal*	Fe Fo M S	ST
Legume			*Calliandra calothyrsus*	Fe Fo Fu S	S
Legume			*Gliricidia sepium*	Fe Fo S	ST
Legume			*Leucaena diversifolia*	Fe Fo Fu S	ST
Legume			*Prosopis glandulosa*	Fe Fo	S
Legume			*Sesbania sesban*	Fe Fo Fu S	S
Other	Neem		*Azadirachta indica*	M P	ST
Other	Egyptian balsam		*Balanites aegyptica*	Fo Fr	ST
Other	Henza		*Boscia senegalensis*	Fo Fr M	S
Other	Kinkeliba		*Combretum glutinosum*	Fo M	S
Other			*Gmelina arborea*	Fo T	S
Other			*Jatropha curcas*	Fu	S
Other	African mahogany (Cailcédrat)		*Khaya senegalensis*	T M	T
Other	Moringa		*Moringa oleifera*	Fo M Fr L	S