Evaluation of Finca Irlands's past and current state of soil fertility and economic and environmental impact assessment

September 2015

Customer Ulrich Walter GmbH

Title Evaluation of Finca Irlands's past and current state of soil fertility and economic and environmental impact assessment

1. Author Tobias Bandel
tobias.bandel@soilandmore.com

2. Author Rainer Nerger
rainer.nerger@soilandmore.com

Date September 2015

Contact address:

Soil & More International BV, Transportweg 7, 2742RH Waddinxveen, Holland

www.soilandmore.com

Table of contents

Summary

Soil & More International reviewed the various reports about the Finca Irlanda, Chiapas, Mexico which were issued between 1963 and 2003. The Finca Irlanda is one of the oldest biodynamic farms in Central America, cultivating mainly Arabica and Robusta coffee as well some cacao and other crops.

Reviewing these reports, Soil & More focused on aspects relevant to soil fertility and productivity. Due to its critical importance, the development of soil organic matter and soil organic carbon levels were assessed in particular as well as their impact on the Finca's carbon and water footprint.

As these reports were compiled by various experts, the results were presented in different formats which made it difficult to establish a consistent benchmark. A few aspects were in common though:

1. The problem of soil erosion
2. Importance to maintain soil cover through mulching
3. Weed management
4. Maintenance of shade trees
5. Application of compost
6. Adjust timing and frequency of compost application including monitoring of soil organic matter

Comparing the available consistent data series from the early 60ies with data from the mid 90ies, a significant decrease of soil organic matter can be observed. Whereas in 1963, average soil organic matter levels of 5% were reported, in 1995 these levels dropped to 2-3%. An isolated analysis from the year 2003 indicated again soil organic matter levels of 5% but due to a lack of supporting information, these data sets couldn't be considered representative.

Although a temporary decrease of soil organic matter could indicate an increased mineralization rate of organically bound nutrients, on the mid- and long-term, the loss of soil organic matter should be avoided. Soil organic matter and the related microbial activity in the soil is an extremely complex topic, but nevertheless, its dynamics should be carefully assessed, especially in tropical climates and soils. In extensively managed tropical farming systems like the Finca Irlanda, a thick mulch layer on the one hand may prevents erosion. On the other hand, it may cause deficiencies in the top soil, as most of the microbes are busy breaking down the organic matter in the mulch rather than feeding the roots, which may cause deficiencies and therefore productivity dips. This phenomenon is also known as poor soils of tropical forests. In this context, the above mentioned aspect or challenge number 6 should be explored a bit further which will be done in the chapter "Feeding the roots vs breaking down biomass."

Overall the well thought through agroforestry system as implemented over decades at the Finca Irlanda, lead to a significant increase of above ground biomass. Related to this, carbon in the soil was build-up over years, leading to a negative carbon footprint of the farm, meaning that more CO_2 is sequestered in the soils of the Finca than released through the agricultural practices. On the long run, the potentially decreasing soil organic matter may influence the carbon sequestration rate, but the currently implemented forest maintenance activities will probably keep the high carbon sequestration rates. The development of the productivity remains to be monitored.

As part of this study, Soil & More linked above mentioned ecological and agronomical aspects to so called "full cost" parameters. These are parameters that indicate the economic value of the natural resources or "commons", which currently aren't considered in the cost calculation of a product or a farm. Different than more intense farming systems, the Finca Irlanda sequesters about **307 tons of CO_2 annually** and potentially **builds-up 337 tons of topsoil** per year. This actually generates an additional **economic value of more than € 37,000** as most of these and other natural resources are maintained or even further developed.

Evaluation of Finca Irlands's past and current state of soil fertility

Soil Organic Matter – the growing media for sustainable farming

Truly sustainable farming is based on a variety of best practices such as cover cropping, reduced tillage, less or no synthetic inputs, energy efficiency, crop rotation or integrated, mixed farming systems, locally adopted varieties, crop residue management and composting and many more.

All these practices can be monitored and assessed using different, practice specific parameters. Focusing and optimizing for only one aspect normally causes tradeoffs or side effects to other parameters. For example planting only trees that have the best carbon sequestration rate, causes a decrease in biodiversity, which leads to an increased disease pressure and may even negatively affect the availability of water as it can be often seen in the well known Eucalyptus forests in Africa.

There is one parameter though, which tackles more than one challenge or aspect. It's soil organic matter (SOM). There is a common understanding within the sustainable agriculture community, that maintaining and increasing SOM levels in the soil is always a good thing to do. It brings structure to the soil preventing erosion and increasing the water and nutrient holding capacity. It adds food for the microbes which they need to feed the roots. It increases as well the variety of microbes, which leads to a natural disease suppression in the soil. All in all a key ingredient for an environmentally sounds and economically viable farming system. A common, healthy soil consists of about 5% SOM, next to minerals, air and water. SOM itself consists of about 2/3 stable humus and the rest of more or less equal shares litter, roots and microbes.

The reports about the Finca Irlanda compiled by Prof. Koepf and Mr. Merckens in 1963 show SOM levels of 5% and more. Identifying these SOM levels, SOM wasn't a major concern. Erosion prevention and the control of weeds were more relevant topics at that stage. Weed growth was a major problem at that stage and Mr. Merckens recommended to introduce low growing legumes which would suppress the weeds while fixing nitrogen from the air. A practice, which still should be implemented today to enrich the soil with nitrogen. Still, both Prof. Koepf and Mr. Merckens had some recommendations regarding the implemented compost and SOM management practices:

1) As the main ingredient of the compost was the coffee pulpa, which tends to have a low pH, they recommended to add some lime to increase the pH, as some nutrients, specifically phosphate are hardly available at low pH-levels.

2) As the production costs of compost apparently increased by over 70% compared to a few years back, they recommended to at least partly switch to the less labor intense "in-situ" composting, rather than composting all the available biomass in compost windrows. Apart from some general remarks, this practice wasn't further described unfortunately, which might lead to the challenges the Finca is facing today: lower SOM and productivity levels.

Two to three decades later, the Finca still looked beautiful and rich in biodiversity but according to the soil analysis, SOM levels went down to about 2-3%. In 1988, Boudewijn van Elzakker from Agro Eco visited the Finca Irlanda and mentioned an interesting aspect in the conclusion of his report. Apart from recommending to apply lime with the compost to lower the pH and facilitate the availability of phosphate, he recommended to revisit the implemented compost applications in terms of which soils should receive compost and which not. This aspect wasn't further elaborated at that stage, but might have been a first observation that the SOM and overall microbial dynamics in the soil wasn't optimal.

In 1989 Mr. Merckens visited the Finca Irlanda again and recommended the use of different plant based liquid manures to enhance the soil life. Why is this so important?

How to manage pruning material and crop residues?

It is one of the most logic, yet often neglected practices in agriculture to return crop residues or pruning materials to the soil. This often unused plant material is full of carbon, nutrients and water. Not returning them to the soil would require compensation for this loss by buying and applying other materials. Unless this plant material is centrally collected as part of the harvesting process, it normally stays in the field, left for uncontrolled decay or incorporated to the soil.

There, these plant materials breakdown, which is driven by two processes: microbial breakdown downwards and oxidization upwards. Pending on the macro and micro-climatic conditions and the soil and vegetation type, one of these processes dominates the other. In order to maximize the recovery of the carbons, nutrients and water bound in the biomass, the microbial breakdown should be the dominant process, as the oxidization means a loss to the agricultural system. The microbial breakdown though is linked to a few challenges which should be considered and which are described in the following paragraphs.

Feeding the roots versus breaking down biomass

Initiated by the photosynthesis, a healthy plant releases enzymes and assimilates through the roots to the soil, stimulating microbial activity, which causes the release of nutrients. In a healthy soil, the nutrients are bound in the bodies of the microbes, which are part of the SOM. To release nutrients, the microbes need energy, which they acquire from some available substances in the SOM and through feeding on each other. This symbiotic circular process is the central cycle of natural plant nutrition.

By adding plant material to the topsoil or putting a mulch layer on the topsoil, additional, easy accessible food is made available for the microbes. This can cause two or more problems.

1) Due to the additional food availability, the microbial activity might get redirected towards the crop residues, which may cause an undersupply of nutrients to the roots as most of the microbes are busy breaking down the crop residues in or on the topsoil. That doesn't mean that crop residue incorporation or mulching should be generally avoided. It is simply a matter of timing. Crop residue incorporation is a very common practice in arable crops, but there is it normally done after harvest prior to a fallow period or prior to a less demanding crop in the crop rotation. In permanent crops, a mulch layer should be added at a time of the crop cycle when the plant is dormant. To support the benefit of a mulch layer or incorporated crop residues, some farmers also actively plant green manure or legumes into the mulch layer in order to provide extra nitrogen, meaning energy to the soil to support the breakdown of the mulch.

If the crop residues or mulch is applied or available in an uncontrolled way all year round, the additional biomass may lead to nutrient deficiency, not in the top soil layer but for the roots, which means a potential decrease in productivity. In the following chapter under "Compost Starter", some recommendations are mentioned to utilize the crop residues or mulch in an effective way.

Challenges

Oxydation of Carbon's and Nitrogen's → Evaporation = LOSS

Microbes in mulch compete with roots on Nitrogen as energy source for breakdown of biomass

Crop residue or mulch layer either oxidizes or attracted microbes and energy from the topsoil

2) Another important, but probably less critical problem might be a change of the composition of the soil food web, which is the totality of all microbes in the soil. In a healthy, humic soil, the majority of the microbes is specialized in building and maintaining humus and providing nutrients as a response to the enzymatic request from the roots as described above. If the microbial activity is diverted towards breaking down crop residues, other groups of microbes, specialized in the breakdown of plant biomass may take over dominance and create conditions, which the humus microbes don't like. It is not very likely that just by adding mulch, the microbial dominance will change in the soil but it may happen. For sure this needs to be considered when adding plant based liquid manures as recommended by Mr. Merckens in 1989 and by Soil & More in 2014 as those added microbes may significantly change the microbial conditions in the topsoil. Spreading the wrong microbes definitely has an impact on productivity.

Economic and environmental impact assessment of the Finca Irlanda

Motivation and objective

According to latest FAO reports, on a worldwide average the area of arable land per capita shrank from 4307 m^2 per person in 1961 to 2137 m^2 in 2007. The reason is simple: due to non-sustainable farming practices such as over fertilization of mineral fertilizers and related soil erosion, annually about 12 Mio. Hectares of arable land are lost globally while the world population tripled in the last 100 years.

In times of shrinking natural resources worldwide such as soil or water, it is of strategic importance for the agricultural sector as well as the national economy in general, to closely monitor the development of fertile soils, accessible clean water, energy etc. and how agricultural practices influence these developments. Apart from the national or worldwide agricultural sector, it is of critical interest to each and every company, active in the food industry or agriculture in general to carefully observe and constantly optimize the use and management of those most essential resources, simply to maintain the agricultural business.

If and at which price agricultural goods will be available in the future is determined by the agricultural practices applied today.

To assess this issue, various impact or resource efficiency assessments have been carried out, but only recently, so-called full cost accounting models have been developed in order to evaluate and monetize external costs such as greenhouse gas emissions, water pollution, soil erosion as well as social and health aspects. Generally speaking, full cost accounting is about considering the environmental as well as socio economic impact of e.g. farming practices. These external costs aren't considered in today's cost calculations of products and productions systems, but nevertheless are real and will be more and more important in the future.

Due to the complexity of this subject, full cost accounting hasn't arrived yet in the companies' daily accounting work. Nevertheless, more and more entrepreneurs at farming or processing level ask for practical full cost accounting tools and approaches to be integrated in their strategies and daily decision making.

Ulrich Walter GmbH took the initiative to work on this issue on a real, company respectively supplier level – at Finca Irlanda. In this case related to the cultivation of biodynamic coffee in Chiapas, Mexico.

As full cost accounting is a „young science", there is still many open questions regarding models, monetization factors, assessment boundaries to be applied etc. but the FAO recently published a first guidance document which has been used as a basis for this study.

The actual result of a full cost assessment is very much depending on the location and management specific conditions of a farm. This study is based on data provided by Finca Irlanda's management and from reports. In general, the more professional and holistic a farm is operated, the better the overall full cost accounting results are expected to be.

The United Nations respectively the FAO has worked for three years on the topic of full cost analysis utilizing extensive surveys, evaluations and stakeholder consultations and recently published a study on this research. The results and approach and recommended parameters of that FAO report were used as the basis for this full cost accounting assessment.

"The economic invisibility of natural capital inputs in the global economy is at the source of ecosystem collapse and prices' volatility. Businesses and nations need to account for the true price of activities by appraising environmental and social externalities, risks and dependencies, incorporating it into decision-making and ultimately, mitigating impacts on natural resources and well-being."

Nadia El- Hage Scialabba, Senior Natural Resources Officer FAO/UN

Scientific Approach

The main aim of this study is to show if biodynamic farms provide additional benefits and services for the environment and society beyond the mere production of healthy products.

The holistic and with it economic sustainability is heavily dependent on the local and product specific factors - ecological but also socio-economically. One of the core issues for the coffee farms is the build-up and maintenance of SOM through the usage of pruning material for composting, which secures soil fertility, a good water holding capacity and prevents erosion. Other full cost accounting parameters such as partnerships, research and energy use as well as employee loyalty and motivation were also identified as important aspects but at a secondary level.

The individual parameters were evaluated based on information provided by the Finca Irlanda management and using a plausibility check with standard modeling techniques. To determine soil carbon, organic matter and nutrient contents and dynamics as well as erosion, the appropriate models were used. The agricultural greenhouse gas emissions and CO_2 sequestration was calculated using the Cool Farm Tool, which is a widely used and recognized tool in the food and agricultural sector. The evaluation of the potential water pollution by nitrate leaching and other pollutants was carried out based on the guidelines of the Global Water Footprint Network.

There are different approaches from industry and research on the consequences of the environmental impacts of farming in monetary terms. In 2014 the Food and Agriculture Organization of the United Nations (FAO) published a report about full cost accounting summarizing the results of a three year multi stakeholder consultation process on this topic conducted by the FAO and other organizations such as FIBL and UNEP. This report presents a generic approach to the overall cost estimate at the farm level and presents further economic factors for greenhouse gas emissions, water use and pollution, soil erosion, fertilizer, land use, biodiversity, socio-economic aspects and individual health. As this report with its scientific approach and recommended parameters was generated by independent institutions, these parameters were used in this present study for Ulrich Walter GmbH respectively its supplier of biodynamic coffee, Finca Irlanda.

Ecological Aspects

The year 2015 has been declared by the United Nations as the international year of the soil. And for good reason. Worldwide, we destroy at an alarming rate our arable soils, the basis of our food and agriculture in general. Critics say over and over that organic farmers require more land due to the partial lower yields. Therefore, conventional farming systems would perform better regarding land use. In reality though and apart from the fact that our current world food problem depends only to a very small part on agricultural productivity, the loss of fertile soil through intensive, not appropriate agricultural practices is much greater than the need for more space through organic farming.

Low food prices put pressure on the farmers to intensify the agricultural practices causing soil overuse, depletion and erosion, which in the case of the climate and soils of the Finca Irlanda can lead to a loss of up to 50 tons of topsoil per hectare and year.

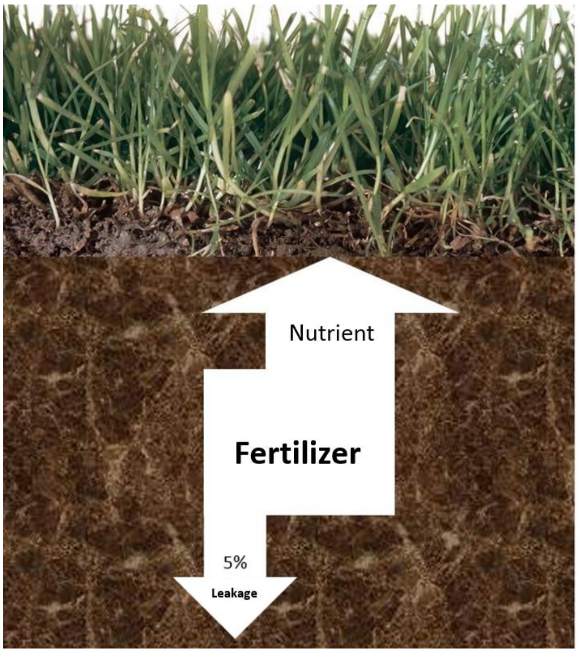
Apart from using compost instead of synthetic fertilizers, the options for sustainable soil management practices are limited in a crop like coffee. Finca Irlanda already uses some of the pruning material, leaf litter and cuttings as well as manure to produce compost to naturally fertilize and build-up the soils.

In the case of arable field crops such as potatoes, crop rotation, green manure as well as different tillage schemes would need to be considered but these activities aren't applicable for a permanent tree crop such as coffee. Still, leguminous cover crops could be used at least at planting stage of new coffee bushes to increase SOM, fix nitrogen and suppress the weeds.

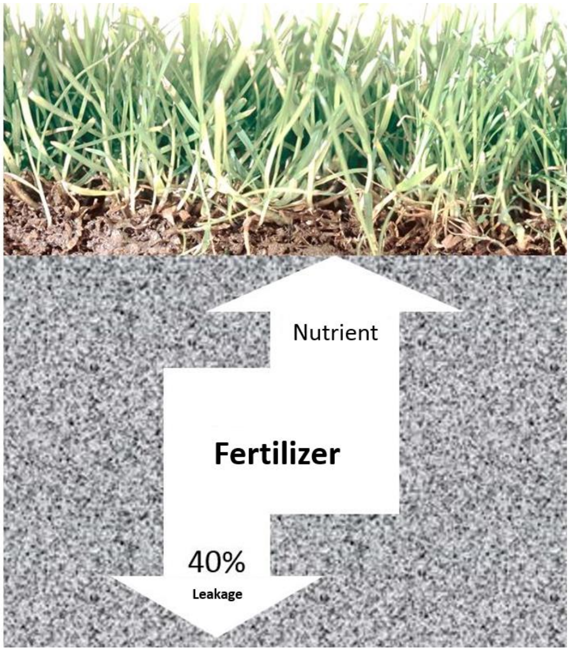
In this context and if the availability of water would allow it, the whole coffee farm could be covered with a not ranking, deep rooting leguminous crop, providing a good structure to the soil, potentially fixing nitrogen and preventing the topsoil from erosion.

What's actually happening in the soil

Soil structure: if you take a crumb of topsoil and look at it under a microscope, you can see a crystalline mineral structure, a so-called clay-mineral which is populated by millions of microorganisms. Closely nested millions of these so-called clay-humus-complexes form the whole of the humic topsoil. The tiny pores between the individual crystals can absorb many times its weight in water, which is why a good humus soil is known to have a better water holding capacity than comparably "poor" soils. This also counts for the nutrients. The clay-humus complexes form a coherent, stable soil structure, which allows only few losses e.g. though leaching. The application of synthetic fertilizers such as ammonia nitrate or urea which are mineral salts, interfere with or even destroy the microbial life causing a collapse of the soil structure. Depending on the type of soil, the loss of structure either leads to severe wind or water erosion or extreme compaction. In both cases, this means a deterioration of the water and nutrient management, as they increasingly run off. As a result of the ever-growing nutrient loss more fertilizer needs to be applied, which, considering the rising fertilizer prices means a significant cost increase - not to mention the impact on groundwater and the environment in general. The underlying idea of organic agriculture including compost application counteracts. Humus structure is built, leaching losses are minimized and nutrients are used more efficiently - in comparison, a plausible model.



Good soil structure means low leakage loss



Bad soil structure means high leakage loss

Compost applications, mulch and no tillage are not only good for soil fertility but also for climate protection. Our top soil is the world's largest carbon reservoir, more than the aboveground biomass and mineral deposits together. Through erosion or other soil degradation, this carbon is released as CO_2. Meaningful, organic farming preserves these carbons in the soil or even sequester additional CO_2. In the soils of Finca Irlanda up to 1.14 tons of CO_2 per hectare are sequestered per year in average. Intensive farm and soil management using mineral fertilizers results in increased degradation of humus and thus release of carbon in the form of CO_2 as well as other greenhouse gases. The FAO defined the costs or value of CO_2e emissions for the environment and society with US $ 113 per ton CO_2e. Factoring in this amount into the cost/benefit calculation of conventional coffee farm, additional costs occur due to the release of CO_2 and these costs aren't accounted for currently. As mentioned above, Finca Irlanda in contrary not only avoid these costs but sequesters CO_2 which can be valuated with the same factor, resulting in a generate benefit of up to € 115 per hectare and year.

CO_2 respectively carbon sequestration are together with the above-mentioned compost application and mulch important ingredients for the build-up of humus and topsoil. Humus thereby has ample positive effects. Firstly, humus is a supplier of top soil material. Secondly and above all humus is the "home" of millions of microorganisms, which ensure natural soil fertility and health. As a result of Finca Irlanda's sustainable agroforestry management, carbon is sequestered but if SOM and humus is actually built-up needs to be investigated. Applying the compost starter on the crop residues at the right time, potentially up to 1.25 tons humus rich topsoil or more could be built-up per hectare and year.

For comparison, the erosion models resulted in up to 50 tons of topsoil per hectare and year, which may occur due to intensive, not sustainable farming practices. The FAO assesses the environmental and societal damage caused by water erosion with US $ 21.54 per ton of eroded topsoil.

Again, a damage to the environment and society equivalent to potentially hundreds of US$'s per hectare and year is opposed to a potential benefit of potentially € 24 per hectare and year through biodynamic farming practices, whereby only the build-up of soil and not the avoided damage is taken into account. Other environmental issues that have been assessed using the parameters recommended by FAO are water use and potential pollution through nitrate leaching resulting from compost application. In addition, the environmental effects of organic pest and disease control in terms of water pollution and biodiversity loss were evaluated as well.

As mentioned above, the guideline of the Global Water Footprint Network was used for the assessment of a potential water pollution. In particular the grey water footprint was evaluated. The grey water footprint is the amount of water needed to dilute an occurred pollution to a pollutant-specific water quality level. Especially with the usage of pest and disease control agents, the grey water footprint can be very high. As the grey water footprint calculation related to pesticide use requires various assumptions, only the grey water footprint related to the potential nitrate leaching has been taken into account in this study. Since Finca Irlanda only applies mature compost, the potential leaching of nitrate from the compost can be neglected.

Considering all these environmental parameter, Finca Irlanda's biodynamic coffee generates an environmental benefit of up to € 139 per hectare and year. This is to be understood as the net benefit, meaning both the benefits as well as some environmental costs are considered. Compared to intense, not sustainable farms the difference can be more than 1,000 € per hectare and year.

Socio-Economic Aspects

In addition to environmental impacts, the FAO has evaluated as well the social and health impact of unsustainable farming and its related costs. As mentioned above, full cost accounting is still a young science, and in particular the definition of the cost related to health damages due to e.g. pesticide-contaminated foods is still very vague. Yet this context and these costs are very real and understandable for many people. The loss of habitat due to erosion, the loss of soil fertility or soil and water pollution can be very real and cause real costs. Another often ignored but now probably most relevant and real factor are social conflicts. Unsustainable short-term, one-sided profit driven farming systems cause a fight over fertile soil, clean water, raw materials which can lead to local and partly regional unrest, or at least forcing people to leave their homes.

To include these real, well understandable but difficult to quantify parameters, the FAO carried out comprehensive surveys to define the costs associated with the loss of livelihoods due to soil erosion, individual health damage through e.g. pest and disease control and social conflicts.

In the regional socio-economic context of the Finca Irlanda, the potential individual health damage caused through the application of pest and disease control measures was evaluated whereas the risk of conflict due to resource scarcity was decided to be neglected.

Overall, the FAO estimates the social costs to be 33 €ents per hectare and year if applicable, whereby almost 90% of these costs may be attributed to the health costs through the use of pest and disease control.

Overall Results

Today's pricing for coffee does not include the environmental and social costs occurring through unsustainable agriculture practices nor the benefits and additional services provided through meaningful and appropriate agricultural practices. Both should be considered in the future for the evaluation of foods.

The following table shows the results for the assessed biodynamic coffee farm, Finca Irlanda in Chiapas, Mexico:

Full Cost Accounting Parameter "external cost"	Cost/Benefit per hectare ("-" means benefit)			
	Biodynamic	Conventional	Difference	
Greenhouse gas emissions	- 115,02 €	59,97 €	174,99 €	the negative value means CO_2 sequestered
Water quality	- €	109,58 €	109,58 €	
Water use	- €	- €	- €	
Soil erosion (water)	- 24,04 €	961,61 €	985,65 €	the negative value means build-up top soil
Loss of biodiversity	- €	12,88 €	12,88 €	
Loss of livelihood	- €	0,003 €	0,00 €	
Individual health damage	- €	0,30 €	0,30 €	
External cost/benefit per kg dry coffee (€)	**- 0,23 €**	**0,96 €**	**1,19 €**	
External cost/benefit per hectare (€)	**- 139 €**	**1.144 €**	**1.283 €**	
External cost/benefit per 270 ha farm (€)	**- 37.546 €**	**308.976 €**	**346.521 €**	

kg soil build-up/erosion	**Biodynamic**	**Conventional**	**Difference**
per kg dry coffee and year	- 2,09	83,62	85,71
per hectare and year	- 1.250	50.000	51.250
per 270 ha and year	- 337.500	10.000.000	10.337.500

kg CO2 sequest./emission	**Biodynamic**	**Conventional**	**Difference**
per kg dry coffee and year	- 1,91	0,91	2,82
per hectare and year	- 1.140	547	1.687
per 270 ha and year	- 307.800	109.400	417.200

Extrapolated to the total area of Finca Irlanda which is planted with coffee of about 270 hectares about 307 tons of CO_2 are sequestered and potentially 337 tons of topsoil are build-up. Taking into account all investigated parameters mentioned above and the corresponding factors of the FAO, Finca Irlanda's biodynamic coffee fields generate a social and environmental value or benefit of about € 37,000 per year. A comparable conventional farm at the same size would cause a social and environmental damage of € 308,000 per year.

Biodynamic agriculture therefore is not a "nice to have" but an economic and environmental necessity.

Conclusion of environmental and economic impact assessment

The theme of the full cost accounting must find its way more and more into our everyday life and business. Ultimately, it is about responsibility - for the sake of the environment and society and thus in our own interest. It is not difficult to understand that each, at least most, of our actions and decisions make a difference. Sometimes more, sometimes less. The approach of the total cost analysis is to take nothing other than these considerations. It is only important that we do so consciously. Through a conscious purchase decision, we can make a positive difference for the sustainable development of agriculture, in our own interest. The aim of this study is to show that aspects such as soil fertility and erosion, water pollution or protection, diversity, or biodiversity loss are not only intellectual luxury topics, but are an economic reality for each of us.

It is very likely that the world population will continue to grow, the planet Earth and the natural resources won't. A gentler, less bad treatment of our natural resources is not enough there. We need to build our resources such as soil, water, biodiversity. We cannot afford to waste these goods. As explained above, Finca Irlanda shows various options and solutions sustainable agriculture may offer. Locally adapted, balanced crop rotations were applicable, mixed farms to ensure a closed nutrient and carbon cycle, enlivening of the soil for the development and maintenance of soil fertility through composting and conservation tillage. All these are essential ingredients to a holistic, sustainable development of agriculture. However, much remains to be developed but initial solutions are there.

Recommendations and best practices

Compost production

In line with the recommendations of Prof. Koepf and Mr. Merckens documented in the reports from 1963 till 1995 and referring to report of Soil & More in 2014, aerobic compost should be produced at the Finda Irlanda to be applied together with the new plants and as a regular treatment. To produce that compost, the pulpa from the coffee processing can be used at about 30-40%, complemented with about 40% dried, woody material and about 20% chicken or cow manure if available. Banana plant biomass should be added to the pulpa due to the high content in potash. The compost should be produced according to the instructions provided by Soil & More in September 2014 and as summarized in the following:

When building the compost pile, always start with the lightest/roughest material followed by green/fresh material and manure last. Always put the heaviest/wettest material last. Repeat this sequence until the pile reaches a height of about 1.25-1.5 meters. The compost pile should have a ground width of 2-3 meters and a length of at least 4 meters. Add about 50 litres of water per $1m^3$ of input material. Add the water in between the layers while building the pile. If available, apply the compost starter 1-2 times in between the layers. Compact the pile 2-3 times while building it. When the pile setup is finished, cover it with straw, banana or palm leaves or a breathing fabric. Don't use plastic to cover the pile as it will stop the flow of oxygen!

Turn the compost pile as soon the core temperate reached and stayed at about 60-70°C for 3 days. In case no thermometer is available, a core temperature of 60-70°C can be verified by testing the core temperature with 2 fingers. If it's too hot to keep the fingers longer than 2 seconds, the temperature is around 60-70°C. Turn again after about 2 weeks and a third time after 6 weeks. The turning should be done in a way that the upper part of the windrow is turned the lower part and the inside out.

The compost is finished when the core temperature reached ambient temperature and when the "water-cress" test results positive. A positive water-cress test means that water cress or a comparable other sentitive plant grows nicely in a compost sample without turning yellow and no other weeds grow. This indicates that the weed seeds were destroyed and no volatile gases are present anymore which would cause a yellow coloration of the water cress leaves.

Compost starter production

Take partly decomposed material form a 5-10 days old compost pile. The material should be hot and should show first signs of decay. In case "difficult/rough" materials should be composted such as straw, coconut husks, palm leaves etc., naturally partly decomposed samples of these materials should be collected and added to the compost pile, which will be used for compost starter production. Use an about 2 kg mixture of the "hot", young compost and the naturally decomposed materials plus ½ kg of molasses, other natural sugars, whey, seaweed powder, trace elements/minerals if available.

Put the materials in the compost starter brewer (as described in the attached document), attach the brewer to the air blower, submerge the brewer in a min. 200 liter water tank and run the airblower for 6-8 hours. If no power or air blower is available, the materials can be put in the 200 liter tank and stirred manually for minimum 1 hour. Stirring it manually is less effective but better than not doing it.

After the compost starter is activated (6-8 hours air blower or 1 hour manual stirring), the compost starter should be applied within 48 hours. The compost starter should be applied while making the compost pile in between the layers or can be spread on the mulch or crop residue layer in the field. If the latter is the case, the previously mentioned timing of application should be carefully studied in order to avoid 1) competition of the microbial activity between the roots and the crop residues and 2) a change of the overall soil condition and microbial population. If applied in the field in order to stimulate the microbial breakdown of the mulch or crop residue layer, the compost starter should be applied while the coffee plant is dormant or in a low production phase.

Compost tea production

Take about 2 kg of mature compost which has been at 60-70°C for 3 days during the composting process as well as about ½ kg of mixed food for microbes as described above. Put the materials in the compost tea brewer as described in attached document, attach the brewer to the air blower, submerge the brewer in a min. 200 liter water tank and run the airblower for 6-8 hours. If no power or air blower is available, the materials can be put in the 200 liter tank and stirred manually for minimum 1 hour. Stirring it manually is less effective but better than not doing it.

After the compost tea is activated (6-8 hours air blower or 1 hour mannual stirring), the compost tea should be applied within 48 hours. The compost tea can be applied using back sprayers or watering cans or using the irrigation system if available. If necessary, the compost tea should be filtered prior to the usage of application equipment such as back sprayers or irrigation systems.

To guarantee an optimal impact of the compost tea, the compost tea should be applied 3 to 4 times at an interval of 7-10 days. Don't use the compost tea all year round as too many nutrients will be mineralized. The timing of the compost tea application should be set 2-3 weeks prior to usual fertilization schedules.

Cover crops

As described by Mr. Merckens, the use of cover crops is very useful for two reasons: 1) nitrogen fixation and 2) the suppression of weeds. When choosing the cover crop varieties, low growing cover crops should be selected, ideally from a leguminous family to benefit from additional nitrogen fixation. In the 1980ies, Mr. Merckens already recommended a few varieties which apparently even were available locally. These varieties were Lotus Corniculatus (German: Hornschotenklee), Lotus Uliginosus (German: Sumpfschotenklee) or Lathyrus cicero (German: Platterbse). There might be other suitable varieties as well. To the best of Soil & More's knowledge, there is nothing specific to be considered regarding timing of sowing the cover crops. For practicality purposes, it should be done just before or during the rainy season in order to make sure enough water is available. It could also we planted as part of the soil preparation prior to new plantings.

Erosion control

Erosion is obviously potentially a major problem but above mentioned best practices contribute to erosion prevention.

Monitoring parameters

SOM was identified to be a key parameter to assess the environmental as well as production related and therefore economic performance of the Finca Irlanda. For this reason SMI recommends to continuously monitor the SOM levels through representative soil samples. As part of this analysis, total nitrogen, nitrate, ammonia and pH should be assessed as well.

As erosion remains one of the critical parameters specifically at non biodynamic farms, an in-depth erosion assessment could be done whereby the following parameter would need to be defined: depth of topsoil layer, soil type, drainage, stone content and cover, precipitation, characteristics of slope (sections), main crops, intercropping and cover crops, type and direction of soil preparation

References/Sources:

FAO Full Cost Accounting Report
(www.fao.org/3/a-i3991e.pdf)

FAO Foodwaste Report
(http://www.fao.org/fileadmin/user_upload/suistainability/pdf/Global_Food_Losses_and_Food_Waste.pdf)

Cool Farm Tool
(http://www.coolfarmtool.org/)

Waterfootprint Network
(http://www.waterfootprint.org/?page=files/home)