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Survey of Agricultural Practices and Alternatives to Pesticide Use to Conserve Water Resources in the Mojanda Watershed, Ecuador

Lukas Schütz *1

1 Faculty of Agricultural Sciences, Georg-August University of Göttingen, Germany
* Corresponding author: *lukas.schuetz@gmx.de*

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Abstract

Agriculture in the Mojanda Watershed is facing rainfall reductions caused by climate change. Reductions of water availability in the Watershed are also due to constant extension of the agricultural activities into the páramo ecosystem above 3000m a.s.l., with this ecosystem having immanently important functions in the local water balance. The application of pesticides threatens the quality of water and with less precipitation contaminations will further concentrate in the outflow. To analyse problems associated with agricultural practices in the area a questionnaire about agricultural practices (28) was conducted and fields (20) were surveyed for pests and diseases with a focus on potatoes (*Solanum tuberosum L.*), tree tomatoes (*Solanum betaceum Cav.*) and peas (*Pisum sativum L.*). Potatoes were infected to a low degree with Phytophthora infestans and according to the farmers the Andean potato weevil (*Premnotrypes spec.*) caused the biggest losses. To combat the weevil the soils are disinfected with toxic Carbofuran (WHO Class 1B). Tree tomatoes showed symptoms of various fungal diseases. Most important was Fusarium solani causing the branches to rot and Anthracnosis (*Colletotrichum gloeosporioides*) causing the fruits to rot. Fungicide applications were correspondingly high. Peas were only minorly affected by Ascochyta blight (*Mycosphaerella pinodes*) and a root rot. Overall 19 active ingredients were applied of which fungicide Mancozeb (WHO class table 5) and insecticide Carbofuran (WHO Class 1B) were applied the most. Approved Integrated Pest Management methods are advised to reduce pesticide use. For tree tomatoes regular cutting of branches infected with F. solani and regular collection and disposal of infected fruits with Anthracnosis are advised. For potatoes plastic barriers around the fields prevent the Andean potato weevil from laying eggs thus reducing infestation with the larvae in the tubers. Local bioinsecticide "Biol" seems effective and without harm to the environment, although not used by many farmers. Organic fertilization promises to restore decreasing soil fertility, water holding capacity and reduce erosion. The here presented alternatives and strategies to reduce pesticide use pose an opportunity to preserve the water resources of the region.

Introduction

Over half of the world's rural poor are smallholder farmers. However they produce a remarkable 80% of food supplies in developing countries. Yet about 75% of those worst affected by malnutrition live in rural areas of developing countries despite their strong connections to food production (Colette et al., 2011). In the Mojanda Watershed in the Province of Imbabura, Ecuador, smallholders dominate agricultural production. They have small land sizes and depend on agriculture for their food production. As indigenous groups (Kichwa and Cayambe) they are segregated from the regular Spanish-dominated Ecuadorian culture and society. They have their own tradi-

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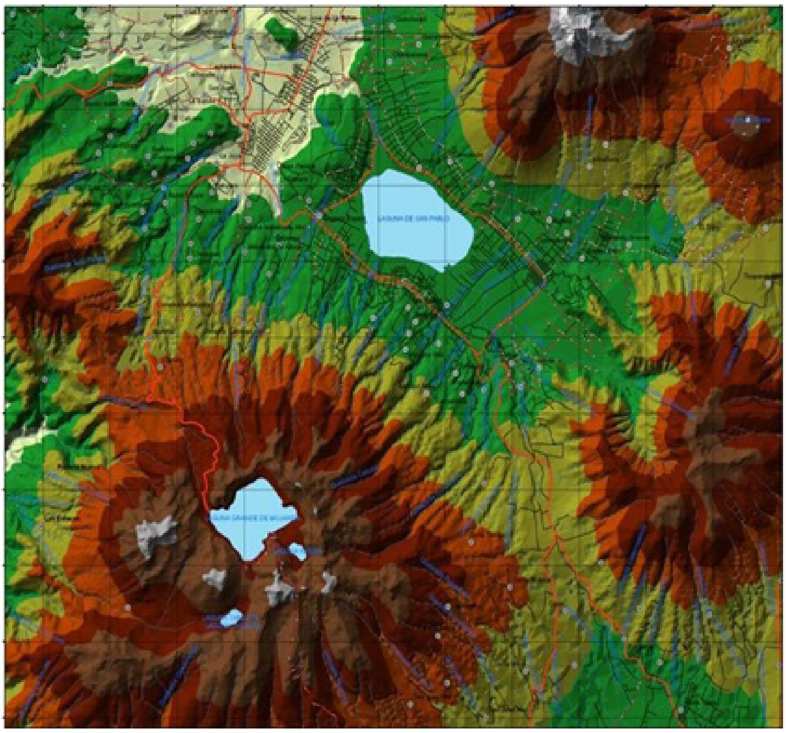

Figure1: Study region between Lago San Pablo and Laguna de Mojanda (O. Rosales, Universidad Tecnica del Norte)

tions and own belief systems. These factors contribute to them having bad connections to markets and little financial means to purchase new technologies or to obtain an education about agricultural practices.

Environmental problems in the Mojanda Watershed have increased over recent years. One of the primary topics of concern in the area is that of water quality and quantity, which are affected by agricultural and household activities, such as sewage disposal and agricultural run-off, leading to a contamination of ground water and water bodies. The intensive agricultural use in the area of the Mojanda Watershed as well as insufficient treatment of sewage water, has led to a rapid eutrophication with high phosphorus levels throughout the year in Lake San Pablo or Imbakucha below (Gunkel, 2002: 42). In recent years it has become widely accepted that climate change will also have negative effects on the water supply in the near future, causing little or no rainfall in some years, and excessive rainfall and/or floods in other years. These effects are foreseen to be additionally strengthened by El Niño and La Niña in some parts of the world, including the study area (Paeth et al., 2008: 284). The pressure on water quality is increasing and with a lower input of water in the catchment areas, the residues from agriculture are increasingly concentrated in the outflow to the lake. Pesticides in drinking water are known to be a serious threat to human health and agricultural practices have a huge influence on the above mentioned problems. It is necessary to analyse them in order to find more sustainable alternatives. The definition of sustainability in this study will follow the Council of Sustainable Agriculture and Rural Development of the Food and Agriculture Organisation of the United Nations (FAO). "(...) such sustainable development (in the agriculture, forestry and fisheries sectors) conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable" (FAO, 1989).

The problems of the area are argued to be environmental but the solution is to be found within the population and its farmers. A cultivation which considers and works with natural processes is found to need less pesticides and additional fertilizers. Many studies focus specifically on one aspect of farming, such as productivity and technology use. In contrast, nutrient dynamics in the soil, effects on biodiversity or the efficiency of extension services through agriculture need to consider all agricultural practices and see the farm as an entire system. Some scholars conducted research about agricultural practices in the whole region (Pandey et al., 2001, Barrow et al., 2008 or Majumder et al., 2010). This study will give an overview of agricultural practices within the Mojanda Watershed and will relate them to agroecosystem processes. With a focus on Integrated Pest Management (IPM) and plant diseases, the main issues for achieving sustainability will be discussed. Additionally, this study is the first in-depth study on agricultural practices in the Mojanda Watershed, and the first to uniquely link the

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problems of the area with sustainability. The following questions are focused on and shall be answered by this study:

(1) What are the main agricultural practices in the study region regarding crops grown, the use of pesticides, cropping patterns?

(2) With a focus on potato (*Solanum tuberosum L.*), tree tomato (*Solanum betaceum Cav*.) or pea (*Pisum sativum L.*), what are the present pests and diseases and how are they presently controlled If used, which pesticides and fertilizers are applied?

(3) Which IPM methods are currently in use and what are the potential IPM methods which could be used to protect water resources of the watershed?

Case study

Data collection

A questionnaire was applied to gain insight on the agricultural production methods in the area. Together with a quantification of pests and diseases of the grown crops and further field investigations, possibilities, which will reduce agricultural pollution, have been sought out.

The data collection process took place in June 2011 and consisted of three stages. First the three crops to be focused on were identified: Potatoes were chosen as a traditional, yet input intensive crop; peas as a leguminous crop and tree tomato as an example for a cash crop. Next, a structured questionnaire (n= 28) was designed to find out about land use and agricultural practices and participants were chosen based on whether or not they farmed potatoes, tree tomatoes or peas. Snowball sampling was used at times to get in touch with other farmers in the study area who farmed these crops. Land sizes of the farms and indigenous heritage are homogeneous in the watershed (Wales, 2012) and found agricultural practices within the sample farmers may be seen representable for the watershed. Information was collected regarding crop rotations, fertilizer use, pesticide and insecticide use and local methods (non-pesticide) to mitigate pest and disease damage. In the third part an assessment of the three crops for damage by pests and diseases was realized. In total 20 fields of the participants of the questionnaire were selected. In three levels of different altitudes two fields of each of the crops were chosen to get an idea about the pest and disease distribution and their general condition. Additionally in potatoes four fields with pesticide application and four fields without pesticide application were selected. The damage on the crops was measured with the estimated severity. Severity was measured by recording the amount of infected or eaten parts of the plants. Diseased plants were assessed for the type of symptoms in order to know if the disease is systemic or local on certain plant organs, including the roots. Diseases were identified according to relevant literature. This assessment was only conducted when it was appropriate which means only when there was an apparent phytosanitary problem. To exclude border effects the counting was always done inside the field. Comparisons between inside and on the borders of the field were done to confirm findings.

Analysis

All collected information was analysed to understand environmental, agricultural and local practices in the Mojanda Watershed. The structured questionnaire on the other hand was interpreted using qualitative analysis (see for e.g. Atteslander et al., 2008) and if possible using descriptive statistics. A content analysis of literature was conducted to formulate solutions to the problems identified. Prevailing diseases were analysed for their risk potential concerning yield losses based upon previous scientific reports. Furthermore, it was tried to identify causes of disease outbreaks. Potential IPM measures and alternatives to current pesticide use are proposed using scientific literature and evaluated concerning their practicability for the study region.

Study area

The Mojanda Watershed is located the mountainous slopes above lake San Pablo and 12,440 ha in size (Figure 1). The precipitation varies around Lake San Pablo between 800-1250mm annually with a dry season between June and September and a humid season from October to May (CEPCU, 2001). Cropping area and therefore study area extends from the lake into the tropical montane forest of the *páramo* (2660 to 3100 m a.s.l.) (Moreno et al., 2007). The *páramo* has a very important hydrological function. The plants which grow there have special physiological features which catch water from the mist of the higher altitudes. The *páramo* collects water and provides the lower areas even in the dry season with water through streams (Buytaert et al., 2007: 23). There is an ongoing trend to shift potato cultivation into the *páramo* thus extending the agricultural border, which poses a threat to the water supply function of this ecosystem.

After the Spanish conquest, the land had been with one exception, under the rule of three haciendas in the whole region around Lake San Pablo. In the 1960s an Agrarian Reform took place under the direction of the Ecuadorian government and the land of the haciendas was distributed among the indigenous population (Mora in Chiu, 2008: 53). The indigenous population was already pushed onto marginal land in the mountains and through the reform the situation became institutionalized. In a study carried out by M. E Wales (2012)

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it was found that nowadays land size per household in the Mojanda Watershed is on average 0.8 h with an average household size of 5.7 persons. The study is based on data collected in three rural Parishes of the Mojanda Watershed, Eugenio Espejo, González Suárez and San Rafael, and can be viewed as reflective of the entire Watershed. 38.6% of the population considered themselves illiterate, while 38.6% reported basic literacy levels. This means that 77.2% of the population can either read or write at only a very basic level or not at all (Wales, 2012). The income which is derived from agricultural activities is with only 16% at first surprisingly low. But almost all of the respondents reported some sort of off-farm employment activities. Agriculture maintains food security and allows them to be independent from the market which guarantees them affordable food. Moreover, an interesting finding of the study by Wales (2012) was that 75.9% of farmers reported a decrease in harvest over the past five years. Furthermore, 35.2% of the sample mentioned a change in climate, such as different rain patterns and less rain. In some communities at the low and intermediate altitude the cultivation of tree-tomatoes as a cash crop has been introduced. Farmers reported to have started to cultivate tree tomatoes in the year of 2008.

Findings

Agricultural practices

The crop diversity that farmers planted was relatively high. Farmers were asked which crops are used in their crop rotation. Traditional crops as well as new crops were part of their rotations. Maize was planted the most with 23 out of 28 farmers. Fava beans (22), potatoes (20) and beans (20) followed. 17 farmers had a tree tomato plantation. Only three farmers within the sample cultivated strawberries. The main crop is maize but often intercropped with beans. Intercropping is very common in the region. Maize is not only planted with beans but also with sambo, a squash species, or fava beans. Other combinations include potato with peas, peas with fava beans, fava beans with potatoes and quinoa with potato. The use of crop rotation was common and only four out of 28 farmers did not rotate their crops. Often tree tomato farmers did not rotate their crops, because the fields have to be close to the house to facilitate harvest and tree tomato farmers often only owned one plot close to the house. Most farmers (21) included a nitrogen-fixing Fabaceae in their crop rotation. On average the fields were left as a fallow for 1.5 months. Fertilizers were applied in different ways. Ten farmers used only manure and likewise ten farmers used only mineral fertilizers. Mostly mineral fertilizers were applied for potatoes. In the case of tree tomatoes mainly manure was used and pea farmers tended to fertilize with manure and a minor percentage with mineral fertilizers or not at all. Overall potatoes and tree tomatoes received more mineral fertilizers and more fertilization in general than peas (see table 1). Peas are mostly produced for auto consumption and in most cases are not sold on the market. Manure is collected and then brought to the field or the animals are kept on the field, either in the fallow period of one month or in case of the tree tomatoes between the stems. The amounts of fertilizers were only noted as high, medium or low because questioned farmers could only tell rough estimates.

Nine of the sample farmers did not use pesticides. 15 of the 19 farmers who applied pesticides did so in a regular pattern such as once a week or once a month. Only 14 farmers though could answer the questions of which products they applied. Differences in the amounts applied are unaccounted. It was found that ten farmers sprayed insecticides and eleven fungicides, seven used both at the same time and nine did not use any pesticides as mentioned above. 19 different active ingredients were found to be in use by the sample in the Mojanda Watershed. On average they used products with three different active ingredients, of which Mancozeb (8) was the most used, followed by Carbofuran (5), Cymoxanil (5) and Metalaxyl (4). Mancozeb, Cymoxanil and Metalaxyl are all fungicides while Carbofuran is an insecticide used to disinfect soils and mostly used for potatoes (27% of all applied pesticides for potato) against the Andean potato weevil and for peas. The most used pesticides for tree tomatoes were fungicides, which reflects the phytosanitary problems with fungi (Table 1). According to WHO classification (Tomlin, 1994), Mancozeb belongs to table 5 (unlikely to present an acute hazard) Carbofuran to Ib (highly hazardous) Cymoxanil to III (slightly hazardous) and Metalaxyl to III. Only rarely used was Chlorpyrifos (3), Benomyl (3), Cypermethrin (1) and Methamidophos (1). However, they belong to higher toxicity classes: II (moderately hazardous), Table 5, II, and IB. Benomyl is banned in Europe. Eight farmers reported that they received some kind of extension service, for example from the CEPCU (a local NGO), training in pesticide handling, training on vegetable growing, pesticide storage training or in the form of extra payment when buying strawberries receive extension services. No public extension service has ever reached the farmers.

Prevalence of pests and diseases and control methods

Potatoes

Three (two under pesticide application, one without) out of eight potato fields showed no symptoms of late blight (*Phytophthora infestans (Mont.) De Bary*). The rest showed symptoms, but percentages of affected leaf area was overall less than 10%. Twelve out of thirteen farmers which cultivated potatoes considered late blight a problem, but the grade of perceived loss due to the disease varied from low to high. The rate of incidence of *P. infestans* was overall low and economic losses are assumed to be marginal especially because potatoes were just about to be harvested. Yet Late Blight is the pathogen which affects potato production the most in Ecuador and most other parts of the world. Its physiological optimum is in cold and moist climates. In areas of continuous potato production like the study region the spores are continuously present in the soil and a reinfection is a permanent threat. However P. infestans cannot be controlled completely by rotation, because the spores are transported by the wind and travel long distances (Pumisacho & Sherwood, 2002). First measure of control is to use resistant varieties. A lot of potato varieties only bear a vertical resistance, which can change quickly and make the variety susceptible again (Pumisacho & Sherwood, 2002). Disease forecasting which reports genotypes helps to identify the right cultivars to combat the disease. The method of spraying the plants with a filtered solution of wood ash in water is one local strategy however without verification.

Nine farmers considered the Andean potato weevil (*Premnotrypes spp*.) a problem and they perceived it more dangerous than late blight. No weevil was found on the field and neither feeding marks on the leaves found, but the larvae were found in storage spaces for potatoes, which proves the existence of the weevil in the area. The Andean potato Weevil poses a big threat to Ecuadorian potato production. If the crop is not managed properly, crop losses can be as high as 80% (Muñoz & Cruz, 1984, cited in Crissman et al., 1998), in others the maximum is 30% (Fankhauser, 1999). Farmers attempt to control the Andean potato weevil mainly by using several applications of often highly toxic insecticides like Carbofuran to disinfect the soil. With spray application timing is crucial because the beetle is only susceptible during the time when they lay their eggs.

However, with continuous potato cropping the weevils can still survive in the remaining tubers. Crop rotation is therefore absolutely necessary to reduce infestation (Crissman et al., 1998). Farmers in the research area reported collecting potato weevil larvae to reduce infestation. Looking at the life cycle and how the beetle reinfests the fields from other fields, this method cannot be successful. Plastic barriers can be a means to reduce the damage caused by the Andean potato weevil. In the study by Kuschel et al. (2009) the barriers were equally effective compared to a farmer's practice of applying insecticides four times in a fallow-potato rotation scheme. In a potato-potato rotation system the effect of the barriers together with one application of insecticides was superior to the farmer's practice. The cost for the new method of plastic barriers was equivalent to two or three pesticide applications per hectare. Plastic is available everywhere, it can be purchased in nearby cities and can contribute greatly to the reduction in insecticide applications.

In one field a few plants were infected with bacterial wilt (*Ralstonia solanacearum Smith*), but no farmer mentioned the disease and seems to be without history in the area. If the incidence of bacterial wilt is low, infected plants should be removed as quickly as possible to avoid a bigger outbreak. Also leftover tubers can maintain the inoculum and the plants should be removed in the next cycle. Using plant resistances would be the most effective way to control bacterial wilt besides avoiding solanaceous crops for a minimum of two years (Priou et al., 2011).

In storage for potatoes larvae and imago of the potato tuber moth complex were found and also farmers reported the problem. The larvae feed on the potatoes and the imago reinfest the potatoes. Potato tuber moth (PTM) is another reason for heavy insecticide applications. PTM granulovirus (PoGV) and *Bacillus thuringiensis* Berliner ssp. *kurstaki (Btk)* provide strong alternatives to manage field infestations of potato tuber moth prior to harvest, thus reducing the risk of tuber infestations in storage (Arthurs et al., 2008). The costs are low and the concentrates of *Bacillus thuringiensis ssp. kurstaki (Btk)* can be obtained in shops and then reformulated with talcum to protect the potatoes in stores (1,50$/200kg potato) (Arthurs et al., 2008: 1544). The International Potato Center (CIP) offers parasitoids against the tuber moth (*Copidosoma koehleri, Orgilus lepidus, Apanteles subandinus*) to national programs of integrated pest management. Used as inoculative biological control they can bring back species lost through intensive pesticide use. The combination of sexual pheromones and insecticides so called attract-and-kill method is another successful IPM measure and proved to reduce males of PTM, both in storage and field situations, by about 90% until 60 days after application (CIP internet resource, 2009).

Tree tomatoes

Tree tomatoes are cultivated between 1800 and 3200m a.s.l. in most of the higher provinces of Ecuador. In recent years the economic value has increased due to the higher demand for tree tomatoes. But because of their value

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and due to its many pathogens, tree tomatoes are also being sprayed intensively.

Six out of eight farmers considered *Phytophthora infestans*, commonly known as "Lancha", to be a problem for their tree tomatoes but losses in terms of harvest and affected plants were generally perceived as low. Incidence of *Phytophthora infestans* in the field was correspondingly low and always stayed under the 10% level of affected leaf area or was not present at all. Five farmers named Fusarium solani link ("Palo Seco") as a problem in their plantation but perceived their losses as intermediate (moderate). *Fusarium solani* occurred in all fields and incidence of affected branches was on average 2.1 branches, however with a high standard deviation. Fusarium solani is the disease agent of a rot of the trunk, known as "Palo Seco" or "Mancha Negra del Tronco". The first symptoms appear in the first stages of development of the plants. Infections in the higher parts of the plants can travel downward easily and then infect the vulnerable stem (Revelo et al., 2006). *Fusarium solani* originates in Ecuador in the province Tungurahua where in the 1990s it had its only distribution area. Now the disease has spread into all major cropping areas of tree tomato (INIAP, 2010). Symptoms of Anthracnosis (*Colletotrichum gloeosporioides Penz*), locally known as "Ojo de Pollo", on the fruits were found in all fields, however the incidence was not able to be counted as farmers remove the infected fruits. All three farmers who estimated losses from the disease considered their loss as high. Alternaria spec. ("Lancha Amarilla") was found in some fields but incidence was very low. Five farmers reported that aphids occupy the tips of the branches and suck on the young leaves. Deformed leaves due to Tomato spotted wilt virus (TSWV) were found in all fields and is probably connected with the presence of aphids. One farmer reported of symptoms that could be the result of an infection with the nematode *Meloidogyne* spec. The nematodes kills off the roots and reduces the normal lifetime of 4 years of the plants substantially. Especially *M. incognita* reduces the life and cropping time of the tree, reducing the total harvest to about 30%; entire plantations had to be given up due to the attack of the nematode (Revelo et al., 2006).

Tree tomatoes should not be planted where other crops of the solanaceous family have been grown in the previous three years. *P. infestans* and other pathogens of *Solanaceae* can survive in the soil and can infect the plantation. Most diseases though are already transferred from the nursery. Farmers need to especially pay attention to the roots and look for galls of *Meloidogyne incognita*. Seeds can also transfer diseases and certified disease-free mother plants guarantee healthy plants (Revelo et al., 2006: 60). Plants in the study area are grown very close to each other and disease can spread easily through the plantation. The farmers intertwine the branches to make the plants more resistant to wind. Revelo et al. (2006) recommends a distance of two meters between the plants. To reduce inoculum of fungal disease like *Fusarium solani* and *Anthracnosis,* infected branches, infested fruits and rotting fruits should be buried or burned (Revelo et al., 2006). Farmers in the study region reported doing both of these control measures, but in the studied fields many fruits, leaves or brancheswere infected, which shows that these measures are not followed thoroughly. Least vulnerable is a grafted hybrid, developed by the National Research Institute of Ecuador INIAP, which resists both the root rot Meloidogyne incognita and Fusarium solani. In general traditional cultivars are more susceptible to diseases. Recommended is the cultivar Común that shows a low susceptibility to diseases and a high acceptance of the consumers (INIAP, 2010).

Peas

In peas all farmers reported the "Lancha" as a major pathogen causing high losses. The disease could not be identified as there are many diseases associated with the Spanish name, which is generally used for fungal diseases. However, some plants showed symptoms of another fungal pathogen which was identified as Ascochyta blight (*Mycosphaerella pinodes Berk* and Blox. or Ascochyta pisi Lib.). Ascochyta blight can be controlled by plowing the stubbles down to deeper soil layers. The removal of crop residues is equally efficient. Furthermore there are resistant varieties, but also certified disease-free seeds can avoid disease outbreak (Infonet-Biovision, 2011).

In two fields a root rot was found in an irregular pattern, which indicates a soil-borne pathogen like Fusarium wilt. *Fusarium wilt* can be avoided with one of the many resistant varieties on the market. Few are resistant as well to Fusarium near wilt with very similar symptoms. The use of disease free seeds, certified or treated with a seed protecting fungicide is again an option. Residues can act as a reservoir of inoculum and should not get in contact with the newly planted crop. A five year rotation prevents a build-up of inoculum in the soil (University of Illinois, 1988). Over all few diseases occurred on peas. The plants were just before floration and more diseases may occur with pod formation and maturation. Most farmers did not use pesticides or mineral fertilizers in their pea crop.

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Table 1: The studied crops (potato, tree tomato, and pea), its diseases, its most applied pesticides and its most used fertilizers. No of answers about active ingredients (ai) used/No of respondents: potato 11/6, tree tomato 20/6, pea 5/2; respondents about fertilizer: potato 13, tree tomato 8, and peas 7

	Diseases	Most applied Pesticides (ai)	Fertilizers
Potato	1. Late blight (*Phytophthora infestans*), 2. Andean potato weevil (*Premnotrypes spp.*) 3. Bacterial blight (*Ralstonia solanacearum*) Potato tuber moth complex	Carbofuran (27%) Mancozeb (18%) Chlorpyrifos (18%) Cymoxanil (18%) Metalaxyl (18%)	Mineral fertilizer 53% Manure 23%
Tree Tomato	1. Palo seco (*Fusarium solani*) 2. Lancha (*Phytophthora infestans*) 3. Anthracnosis (*Colletotrichum gloeosporioides*)	Mancozeb (25%) Benomyl (15%) Carbendazim (10%) Cymoxanil (10%)	Manure 50% Mixed 37,5%
Pea	1. Ascochyta blight (*Mycosphaerella pinodes*) 2. Fusarium wilt (*Fusarium oxysporum*)	Mancozeb (20%) Carbofuran (20%) Cymoxanil (20%) Acarex (20%) Propineb (20%)	Manure 42,9% Mineral fertilizer 28,6% None 28,6%

Local methods used against pests and diseases

There are some methods used by the sampled farmers to combat pests and diseases organically, which also meet IPM/organic principles. Most common was the application of "Biol" as a spray. "Biol" is a mixture of the manure of cattle or other livestock, whey, sugar cane molasses (Panela), water, ash, baking soda and some herbs. It was found that the ingredients are not always identical; one version also contained pig urine, cow milk and an egg and others left out whey or sugar cane molasses. The following plant names were part of the mixture (missing Latin names are in Spanish or Kichwa): Rue (*Ruta spec.*), Eucalyptus (*Eucalyptus spec.*), angel's trumpet (Brugmansia spec.), Berro (*Nasturtium officinale W.T. Aiton*), Marco, stinging nettle (*Urtica spec.*), chili rocote (*Capsicum pubescens Ruiz and Pav.*), tobacco (*Nicotiana spec.*), alfalfa (*Medicago sativa L.*), peas with flowers (*Pisum sativum*) and vetch (Vicia spec.), chilca (*Baccharis latifolia*), garlic (*Allium sativum L.*), verbena (*Verbena spec.*). The mixture is moved every two days and then left to ferment for some weeks. With the herbs included in the mixture it is a natural insecticide. Chili (Levinsohn, 1976), tobacco (Casanova et al., 2004), garlic (Tedeschi et al., 2011: 488, Debkirtaniya et al., 1980) and rue (Vaughan and Judd, 2006: 137) are known to be effective insect repellents. In B. latifolia Zapata et al. (2010: 103) found inhibiting effects of essential oils of B. latifolia against *Aspergillus fumigatus* Fresen and Roja et al. (2007) found an antibacterial effect against gram positive bacteria. Tobacco has been used for a long time to control insects, but its alkaloid alone is stated to not be very effective (Tomizawa & Casida, 2009: 262). One farmer reported using an ash against powdery mildew and fungal diseases of tree tomatoes and in potatoes. He would soak the ash in water, then sieve out the big particles and spray the ash water on the infected plants. By reducing the moisture and the bioactive components of the ash the survival rate of arriving and germinating spores could be smaller. Also, the ash particles probably occupy possible infection sites of pathogenic fungi and hinder an infection. However, these effects would only last until the next rain. The traditional crop "chocho" (a lupine variety) has high levels of alkaloids and has to be cooked several times to remove bitterness from the seeds. People in the area use the water leftover from cooking and spray their crops to combat pests.

State of the agroecosystem

The cropping area is located on and between the ridges of the mountain slope towards the Mojanda Lakes. The only flat land is located around Lake San Pablo. The land located here has a good water supply but in the higher altitudes agriculture is limited by the water supply and depends on rainfall. Cash crops like strawberries and tree

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Table 2: IPM measures for present pests and diseases

Crop	Pest or disease	IPM measure
Potato	*Phytophthora infestans*	Resistant varieties combined with disease forecasting Avoiding Solanaceae in crop rotation
	Andean potato weevil	Plastic barriers
	Ralstonia solancearum	Resistant varieties Soil radiation Avoiding Solanaceae in crop rotation
	Potato tuber moth	*Bacillus thuringiensis* and *PTM granulovirus* Release of parasitoids *Copidosoma koehleri*, *Orgilus lepidus, Apanteles subandinus*
Tree tomato	*Anthracnosis*	Removal of infected and rotting fruits
	Fusarium solani	Prune infected branches
Pea	*Ascochyta blight*	Deep plowing of stubbles Resistant varieties
	Fusarium wilt	Crop rotation Resistant varieties

tomatoes require irrigation and are planted close to the water sources. Other more traditional crops like quinoa, amaranth and maize are well adapted to the water scarcity. The water catchment of the *paramó* is channeled into the shrubs and then transported to the households in the villages. Only with excessive rainfalls the water reaches the lake. Yet terraces were not constructed to reduce the degree of slope and improve water holding capacity.

However, to reduce wind speed and erosion farmers constructed a wind protection with walls made out of adobe/loam called "Ardogón". They have been identified by the author as a habitat for soil inhabiting bees and bumblebees and contribute to pollination in the area. Hedges fulfil a similar function, including retention capacity for water and regulation of soil moisture content, and provide many services in an agronomic context as well as for nature conservation. In the research area hedges are abundant and can be found next to many fields. The natural vegetation has vanished in the intermediate altitudes. It has been replaced by Eucalyptus plantations, which is the case in other Andean regions as well (Carse, 2006). *Euphorbia laurifolia* ("Lechero") is the most planted shrub and believed to be a holy plant to the Kichwas. It is planted on the boundaries of the field and fulfils a protective function. The wood is never used for fire and the tree is highly respected (CEPCU, 2001). Other plants found in hedges are *Agave spec*., *Baccharis latifolia Ruiz* and Pav. ("Chilca"), Izzo (a 90cm high Fabaceae with blue flowers) and *Eucalyptus spec*. *B. Latifolia* is a fast growing shrub, 2m high and 3m wide.

They are used as a living fence and can fix soils on slopes and terraces (Efloras, 2008). *B. latifolia* seems to be of special interest to insects. Their flowers are visited manifolds. With 20 sweeps with an insect net 68 morpho species including 13 small wasp species, possibly parasitic, and 6 spider species were found, which shows the high biodiversity and its function in the ecosystem.

Conclusion

The Mojanda Watershed faces rainfall decreases in the future. The El Niño and La Niña phenomena are expected to increase in the future and weather patterns are expected to change. Traditional agricultural knowledge is at risk because planting calendars are adapted to the bimodal rainy-dry season and thus livelihood and financial outcome. These issues will be increased furthermore if the extension of the agricultural border into the *páramo* continues and its crucial water collection function diminishes. Decreasing precipitation concentrates the outputs of agriculture in the runoff water and pollution is expected to increase with current pesticide application praxis and type of pesticides applied (e.g. Carbofuran WHO class IB). Some products were banned in Europe and are even banned in Ecuador. With 68% of the questioned farmers there is a moderate level of pesticide users.

However, 79% of the pesticide users applied them on a regular basis without checking for the pest or disease status and 26% did not know which products they apply. Knowledge about the pest and disease species, pest cycles is crucial to do regular scouting of their fields and to get the right timing for application to reduce pesticides and costs.

However, pesticides can also be replaced completely. There are some general methods included in the IPM principles to avoid a pest or a disease outbreak such as crop rotation, synchronous planting, certified seeds and the use of resistant cultivars. Crop rotation is always aimed at eliminating the pathogen from the soil either by time without the presence of the host of the pathogen or by antagonistic characteristics of plants which can accelerate this process. Suppressive soils can increase the effect where antagonistic microorganisms block out the pathogens. Synchronous planting enhances the effect of crop rotation when a whole area follows the same rotation. If resistant varieties are available they are the most powerful tool. Tree tomatoes do not have a very broad distribution and resistant varieties do not exist for the anthracnosis, which reduces yields substantially. The only alternative to pesticides is to collect the infected fruits or to test other products already applied in other crops.

Local farmers have been shown to use some alternatives to combat pests like the preparation of "Biol", the application of left-over water from cooking chochos or the spraying against fungal diseases with an aqueous solution of wood ash. Especially "Biol" seems to be an effective bio pesticide. Yet the recipe differs and the formulation could be optimized in further research to distribute the knowledge or the product as a cheap alternative to pesticides. For other, commercially available and ecological sound, pesticides or biocontrol agents like PTM granulovirus, Btk or parasitoids the farmers may not be able to have access. Public institutions if not the pesticide sellers are challenged to provide these inputs. The same is valid for certified seeds. For traditional crops certified seeds are less important than for non-traditional crops as they usually show a high adaption to the environment. An interesting IPM method against the weevil was found to be plastic barriers around the fields. If seed potatoes are checked for an infestation, the barriers prevent the flightless weevils from migrating onto the fields (Kuschel, 2009).

With education it is possible to reduce pesticide pollution. IPM methods require substantial knowledge on the farmer's side. Farmers in the study area are only educated at a basic level and furthermore they lack access to information about agricultural practices and the agricultural market.

People in the region reported about lower yields compared to previous years (Wales, 2012). The fallow time has been reduced and does not seem to allow the fields to restore the soil fertility. Applied fertilizers do not seem to replace extracted nutrients either and erosion plays another role in the reduction of soil fertility. The NGO CEPCU (2001) had already observed erosion in the most cultivated parts between 2700 m a.s.l and 3200 m a.s.l..

The people of the Mojanda watershed live in a fragile ecosystem. Water is at the centre of attention and its quantity and quality are at risk. Agriculture is connected highly with the identity of the people, yet the financial outcome is marginal. Extension service could mitigate agricultural problems and push forward more sustainable farming practices, but to solve the situation a development plan for the region is needed to reduce the pressure on the land and the people and water resources.

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Conflict of Interests
The author hereby declares that there is no conflict of interest.

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