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Does Sustainable Intensification Protect Forests from Deforestation?

The Case of Silvopastoral Systems in Caquetá, Colombia

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Declaration

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Abstract

Sustainable Intensification (SI) of forage-based agricultural systems is pursued in order to improve productivity of pastures as well as local livelihoods while reducing the carbon footprint of livestock production and providing ecosystem services. Production technologies such as Silvopastural Systems (SPS) were shown to allow for a higher stocking rate (animal units per hectare) while improving a number of other sustainability indicators such as biodiversity. Therefore, SPS are often regarded as methods of SI. Based on the case of SPS, this thesis analyses whether SI can support in reducing deforestation. Basic economic theory proclaims that profitable operations will be expanded. Nevertheless, the view exists that “different forms of sustainable intensification hold the potential to reduce pressure on tropical forests […], if complemented with appropriate policies” (Landholm et al. 2019).

This thesis investigates SPS as a case of SI in livestock farming in the Colombian department Caquetá. The analysis consists of two parts. The first part analyses whether SPS in Caquetá can be seen as a form of SI. The second part focuses on the effect of intensification on deforestation. The main data source is a survey of 2016 of 341 farm households. Results of a participatory workshop and expert interviews complete the data source. For the first part, households are separated into farmers that manage SPS and farmers that don’t manage SPS. The two groups of farmers are compared based on three indicators of intensity (annual milk yield per hectare, the annual labour days per hectare and the stocking) and on their distance to the national highway. In the second part, the influence on farmers’ forest reserves of these four variables and of the dummy SPS is modelled with linear regression.

This study does not find significant differences in intensity between farmers with SPS and farmers without SPS. Likewise production intensity did not have a significant effect on forest reserves. Instead, it was found that farmers with SPS had significantly lower forest reserves than farmers without SPS.

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Abbreviations

AIC – Akaike Information Criterion

AU – Animal Unit

ISS – Intensive Silvopastoral Systems

GHG – Greenhouse Gas

SI – Sustainable Intensification

SAL – Sustainable Amazon Landscapes

SLUS – Sustainable Land Use Systems

SPS – Silvopastoral Systems

TFP – Total Factor Productivity

TLU – Tropical Livestock Unit

UNIAMAZ – Universidad de la Amazonia

ZALF - Leibniz Centre for Agricultural Landscape Research

Table of Content

Figures

Tables

1 Introduction

1.1 Sustainable Intensification Facing Population Growth and Climate Change

World population is expected to grow to 9.6 billion people by 2050 (Rao et al. 2015). Accordingly food requirements will increase immensely. A need for a 70% increase in food production compared to the level of the year 2000 is estimated (Bruinsma). Agricultural yields can be increased in two ways: 1) the expansion of agricultural land and 2) the intensification of agricultural production per hectare (Tilman et al. 2011).

Agriculture’s importance in feeding humanity is undeniable. Still it faces immense criticism for unsustainable production methods. Threats like climate change and biodiversity loss are in part produced by agriculture itself. Being the largest land use, agriculture is said to be the largest driver of biodiversity loss through processes like conversion of ecosystems into farmland, intensification of management, or the release of pollutants (Dudley and Alexander 2017). It is estimated that agriculture is responsible for about a quarter of global green-house gas emissions (GHG) through land clearing, crop production, and fertilization (Burney et al. 2010) .

The term Sustainable Intensification (SI) was coined as a target to tackle both sides: increasing yields without adverse environmental effects and without the extension of agricultural areas (Pretty and Bharucha 2014). In reality however agriculture and forests are often rival land-uses as the next paragraph shows.

1.2 Livestock Production and Deforestation

The Amazon forests is described as the largest forest ecosystem in the world, hosting 10% of known species and storing the amount of Carbon that is emitted globally in a 15 year span (Dávalos et al. 2014). Forest protection is needed to meet climate, biodiversity and local livelihood goals (Ngoma et al. 2018). Nevertheless efforts to reduce the rates of conversion from forest to other land-uses keep being unsuccessful. Amazonian forest fires in Bolivia and especially Brazil have led to worldwide attention (eg. Oliveira Silva 2019, Escobar 2019). In Colombia rates of deforestation have been peaking in recent years as a consequence of the peace treaty of 2015 (Eufemia et al. 2019).

A multitude of drivers of deforestation have been identified: the expansion of arable land, the need for firewood of local population, tropical timber and export crops to increase a country's foreign exchange earnings, extraction activities such as gold and oil, urbanization and development (Culas 2012). Agriculture and livestock production play a major role. In fact worldwide agriculture expansion into forests is responsible for 80% of deforestation (FAO 2017).

In many parts of Latin America the predominant form of livestock production is double purpose (milk and meat) extensive cattle ranching (Dávalos et al. 2014). This is the case especially in regions that are located next to primary forests, so called agricultural frontier regions. Production methods are not adapted to local soil conditions and therefore productivity of new pastures usually drops sharply after 5 to 15 years with stocking rates (animal units per hectare) decreasing on average to as low as one head per hectare (Kaimowitz and Angelsen 2008, p. 7). When productivity drops farmers either have to clear new areas of forest if available or sell their farm to move further into the forest. Pasture expansion is found to be the main cause of deforestation in many parts of Latin America (Pendrill and Persson 2017).

SI has been suggested as a target to tackle the issue of deforestation by livestock production (Landholm et al. 2019). Silvopastoral Systems (SPS) are among the many methods that have been suggested and applied to reach the objective of SI.

1.3 Silvopastoral Systems for Sustainable Intensification

Silvopastoral Systems (SPS) are a form of agroforestry and often associated with the target of SI. In SPS fodder plants are combined with shrubs and trees. Different systems of SPS can be identified globally, with some dating back up to 4500 years (Stevenson and Harrison 1992). In literature different classifications are used. Mauricio et al. (2019) name the following subcategories: SPS using natural forests, grazing in planted forests, SPS using orchards, SPS using tree plantations for industrial purpose, SPS using introduced trees and shrubs, SPS using multipurpose trees, SPS for intensive cattle production.

The inclusion of trees and shrubs on pastures is expected to bring about a multitude of benefits. Among them are improved animal nutrition, lower temperatures through tree shadow, production of marketable timber, fixation of nitrogen, reduced soil compaction and provision of habitats for wildlife (Murgueitio et al. 2011). Solorio et al. (2017)

present SPS as productivity enhancing by reducing input costs while increasing environmental sustainability. Additionally the systems are claimed as mitigation strategies against climate change whilst enhancing carbon storage. The authors see SPS as “one of the best strategies for livestock production” (Solorio et al. 2017, p. 247). Mauricio et al. (2019) see the potential for SPS to promote SI by increasing the production of milk, beef and other goods with low fossil fuel input, high biodiversity and biomass production, and by increasing animal welfare and saving water. At the same time landscapes are recovered and ecosystem services provided. Furthermore the systems are said to promote income diversification and help to meet food security needs. Landholm et al. (2019) investigate the greenhouse gas mitigation potential of SPS. They find that, while agricultural productivity is increased, GHG emissions can be reduced by 2.6 Mg of CO2 equivalents per hectare and year, offsetting the increased emissions through additional animals per hectare. At the same time the practice contributes to the restoration of degraded landscapes. Rivera-Herrera et al. (2017) analyse productive and environmental benefits of intensive Silvopastoral Systems by comparing studies focusing on Colombia from the last 15 years. Their findings suggest that annual milk and meat production are increased 2 to 5 times per hectare compared to conventional systems while decreasing methane emissions due to changes in fodder intake of animals. Stocking rates rose from originally 0.8 AU per hectare to between 2.9 and 3.8 (depending on region of study).

Evidently the distribution of SPS as an alternative to traditional pasture systems entails promising benefits. So far however it seems that these benefits are mainly demonstrated in laboratory settings, with information mostly generated on model farms. Adoption among farmers remains limited, even though increasing efforts have been made to spread SPS. Zabala (2015) and Lee (2019) point out reasons: from a farmers perspective the fact that capital is fixed long-term before it pays off, the increased labour demand, and the perceived complexity of the system are hindering factors. Socioeconomic conditions of farmers can also play a role, for example uncertainty of land tenure. The potential of SPS to fulfil the target to sustainably intensify livestock production can only be reached when adoption happens on a bigger scale.

In the process of adoption farmers adapt a new production technology according to their needs (Zabala 2015). It might turn-out that through this adaptation process the technology is changed in a way that the promising results on model farms cannot be achieved in the practical farm context. Therefore effects of SPS still have to be proven in heterogeneous real world farm environments.

1.4 Technological Progress and Sustainable Agricultural Intensification

To analyse SI economically, a differentiation between technological change and agricultural intensification is helpful. In economic terms new agricultural production technologies such as SPS mean technological change, or more precisely: technological progress. Technological progress alters total factor productivity (TFP) (Nicholson and Snyder 2012, pp. 311–315). This implies that the production function of a farmer is changed, and therefore the possible combinations of input factors (capital, labour and land) can produce more output than before. Technological progress either means that the same output can be achieved with a reduced amount in total physical inputs or that output is increased with the same amount of inputs[1].

Technological progress can also modify the relation of input factors to each other next to changing the relation of output to input. The factor intensity describes the relation of one input factor either to another input factor or to output. Commonly the relation to the input factor land is used. A new labour-saving technology uses less labour per hectare while a labour-intensive technology needs more labour per hectare. A yield increasing technology increases output per hectare without changing labour or capital relations. Technologies are sometimes described as land-saving, especially in the context of SI (Angelsen and Kaimowitz 2001a, p. 22). In this case the input factor land is compared to output. Accordingly a land-saving technology needs less land for the same yield.

Agricultural Intensification is defined as an increase in yields per unit of land which can be achieved through technological progress or through factor substitution (Villoria et al. 2014). This means that intensification does not necessarily entail an increase in TFP. It is also possible to substitute the input land with an increase in all other inputs such as chemical fertilizers and labour without changing the production function.

SI includes the aspect of sustainability into agricultural intensification. The definition for both aspects, sustainability and intensification, differ among scholars. Lerner et al.

1 Another definition for technological change is a change in production processes that alters net profit. An increase in TFP will increase profits as long as prices stay constant (Angelsen and Kaimowitz 2001a, p. 20.)

(2017) define SI as “increasing yields while also increasing the provided environmental benefits” which can be achieved in two ways: through land-sparing or through land-sharing. Land-sparing intensifies production on one part of the land while the other part is conserved. For land-sharing the agricultural procedures itself provide ecosystem services while increasing productivity[2]. Other authors ask for environmental impact-neutrality: “increasing yields without adverse environmental effects and the extension of agricultural areas” (Pretty and Bharucha 2014, The Royal Society 2009). Similarly Firbank et al. (2013) define a farm as practicing SI “if food production per unit area had increased […] and none of the environmental variables had deteriorated”. Gadanakis et al. (2015) see SI as “the process of increasing agricultural production per unit of input whilst at the same time ensuring that environmental pressures generated at farm level are minimised”. While the first definition expects an improvement in the provided environmental benefits others only ask for non-deterioration and the last definition even merely implies minimised damage.

In summary SI can be achieved through an increase in yields per unit of land. This does not necessarily need to come from technological change but can be achieved through factor substitution. It is to be expected that a substitution of land for chemical fertilizers and herbicides will be the easiest way to increase yields per hectare (especially in regions with high labour costs). This strategy however most likely entails negative environmental effects. Therefore it is possible only in agricultural intensification but not in the more rigid SI. In fact SI narrows down the possible strategies to achieve the target of intensification.

1.5 Deforestation in the Context of Agricultural Intensification

1.5.1 Overview of Theoretical Literature

SI is agricultural intensification that emphasizes sustainability. Therefore, to analyse the effect of SI on deforestation, it is necessary to analyse the effect of intensification. The following passages present the theoretical approaches. Empirical findings are presented afterwards.

Two schools of thought can be distinguished that analyse the effect of agricultural intensification on the amount of land that is used. The first one is coined ‘the Borlaug Hypothesis’ after the Nobel laureate of 1970, Norman Borlaug who had a key role in

2 This differentiation is especially interesting for SPS as it integrates trees that can be seen as a secondary forest.

the Green Revolution (Borlaug 2007). According to this school of thought higher productivity will automatically free up land, which will be spared from deforestation. In effect the Green Revolution is said to have saved millions of hectares by intensifying agricultural production through new varieties, fertilizers, irrigation and pesticides (Borlaug 2002). Controversial literature was introduced in 2001 by Angelsen and Kaimowitz (2001a) in their book on agricultural technology and deforestation which started a trend of research. They use neo-classical economics to say that generally profitable ventures are expanded and thus an increase in productivity will lead to more deforestation. This is often called “the Jevons paradox”. Angelsen (2010) discusses the implication of agricultural policies on deforestation adding to the analysis of agricultural rent the analysis of forest rent including local and global public goods such as water catchment or carbon sequestration and storage. Hertel (2012) harmonizes Borlaug and Jevons by emphasizing the role of the demand elasticity that farmers face. Ngoma et al. (2018) focus on climate-smart agriculture and examine “factors which make land-sparing following sustainable intensification more likely to occur” (Ngoma et al. 2018, p. 179). They include policy and intervention suggestions for win-win scenarios (for farmers as well as for forests). The approaches are hereafter presented in detail. Emphasis is given on the work of Angelsen and Kaimowitz.

1.5.2 The Global Food Equation - Borlaug Hypothesis

The Borlaug Hypothesis starts at the global food equation which says that the area of food production multiplied by the average yield must equal the food consumption per person multiplied by world population (Ngoma et al. 2018, p. 179).

$$\begin{aligned} &area\ of\ food\ production * average\ yield \\ &\qquad = food\ consumption\ per\ person * world\ population \end{aligned}$$

Keeping consumption and population constant and increasing average yield would mean a reduction of area for food production which would result in sparing land for forests or other uses. For this reason it is also called the land-sparing hypothesis. Inherent to the above formula is the assumption that food is not produced for profit reasons, therefore it is also referred to as Subsistence Hypothesis (Angelsen et al. 2001).

1.5.3 Perfect Market Approach – Jevons Paradox

Angelsen et al. (2001) analyse the effect of technological change on deforestation based on approaches of Ricardo (1891) and von Thünen (1966). As shown before (see 1.4),

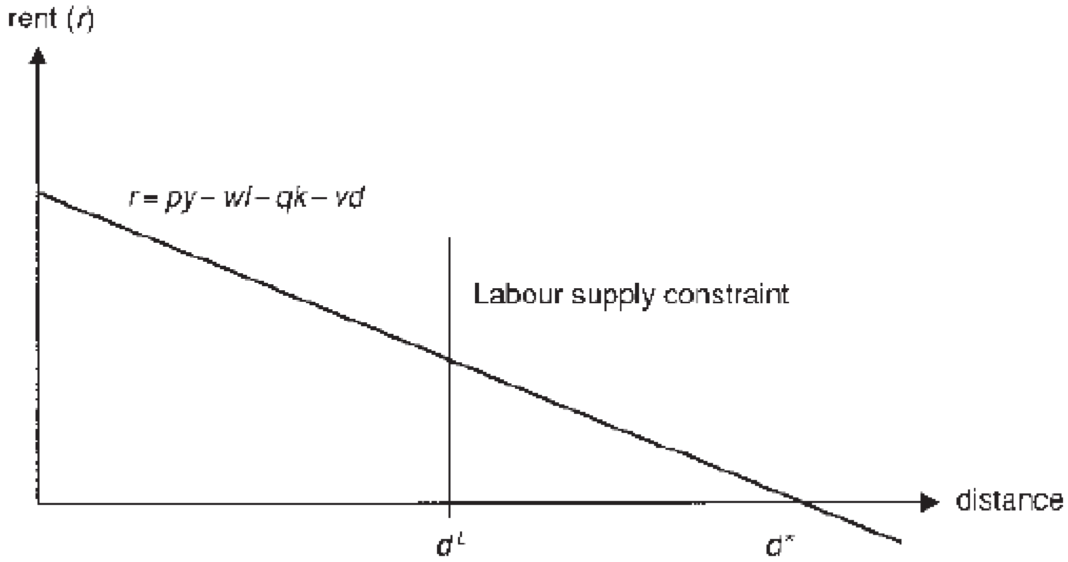

Figure 1: „The agricultural frontier“ (Angelsen and Kaimowitz 2001a, p. 24)

intensification can, under certain conditions, fall into the definition of technological progress. For this reason it makes sense to follow their argumentation.

For simplicity it is useful to start with the perfect market case, where farmers can buy and sell as much as they like to given prices, inputs and outputs are homogenous, and all actors have perfect information. It is clear that this is an unrealistic scenario at the forest frontier, but a good starting point for an analysis. The case of a single farm that produces a single commodity is considered. The applied technology has fixed-inputs, so substitution between inputs, e.g. labour and capital, is not possible (Leontief-type technology). The farm is assumed to be surrounded by abundant forest land with zero costs for acquisition of land and for the expansion of agricultural production. However the farmer's transport costs for inputs and outputs are depending on distance, which leads to diminishing land rents the further they expand. With these assumptions the profit function looks as follows:

$$r = py - wl - qk - vd \qquad (1)$$

Output price (p), yield (y), wage rates (w), labour requirements per hectare (l), price of capital (q), capital requirements per hectare (k), transport costs per km (v) and distance (d) determine the profit per hectare, also called the land rend per hectare (r).

Farmers will then expand until the land rent for the next hectare is zero:

$$r = py - wl - qk - vd' = 0 \qquad (2)$$

d' is the outer limit of the farm. This is depicted in the graph in figure 1, where rent is dependent of d and all other variables are kept constant.

Introduced technological progress can have the following consequence. Either 1) yields per hectare will increase, 2) labour requirements per hectare will decrease or 3) capital requirements per hectare will decrease or 4) a combination of these. All options will increase the rent per hectare at any given distance and push the graph upwards increasing d' (as long as prices stay constant). Therefore in the perfect market model technological process will expand the agricultural frontier and stimulate deforestation.

1.5.4 Input Constraints

The model explained above assumed perfect markets. However, for subsistence farmers and in regions that are far from developed areas (e.g. forest frontiers), markets are often far from perfect or do not even exist. The effects of technological progress change when a farmer faces input constraints.

In remote areas farmers often cannot afford to hire labour or the supply of labour is limited. In this case the farm is completely dependent on family labour. This limits the amount of land they can cultivate. The labour supply constraint is depicted in Figure 1 (d^L). The same principle applies to a constraint in capital supply, which is also not untypical for subsistence farming in remote areas. Technological change may modify the input constraints that farmers face and motivate them to change the allocation of their scarce resources. Given a situation of input constraints, the effect of technological progress on deforestation depends on the type of progress and on the type of constraints. When the limiting factor for expansion is labour and a new labour-saving technology is introduced, the free labour can work additional land. Thus, the new technology will stimulate deforestation. As an example, a farmer can work 2 hectares by only using simple tools. They cannot hire additional labour but have unlimited capital. So they can use their capital to acquire a new production technology, e.g., a tractor. With this tractor they can cultivate 10 hectares without changing the labour supply. The tractor is a labour-saving but capital-intensive technology. It allows the farmer to expand their territory 8 hectares into the forest. In other words, a labour-saving technology fosters deforestation under the premise of labour constraints. A new labour-intensive technology however will bind labour which leads to a reduction of farmland. Thus, "technological changes that allow farmers to use less of their scarce factor will boost deforestation. Innovations that are intensive in the scarce factor will reduce deforestation" (Angelsen et al. 2001, p. 25).

1.5.5 Distance to the Forest Frontier

Based on Boserup (1965) it is expected that "farmers will exploit the extensive margin before the intensive one" (Angelsen 2010, p. 19640). This means that, when farmers face constraints in some inputs but abundance in another, they will first make intensive use of the abundant one. As an example, a farmer, who has land cheaply available but reduced access to labour and capital, will be inclined to use labour- and capital-saving technologies. A labour- or capital-intensive technology will only be applied once land becomes scarce.[3] As a consequence the distance to the forest frontier matters, since it is assumed that land is abundant and available at almost no costs near the forest frontier. The further away from the forest the higher are land prices. Accordingly, it is expected that farmers closer to urbanization are more likely to introduce a new labour or capital intensive technology as the factor land becomes less available.

1.5.6 Further Factors Changing the Outcome of the Simple Model

Farmers Characteristics

Deforestation also depends on the attitude of the farmers. For example, they can be either oriented to increase their financial wins (commercial farming) or they are looking to fulfil a constant level of material well-being (subsistence farming). (Angelsen et al. 2001) assume a family farm without external contracted labour. The farmer's labour supply now depends on the return of labour. They can freely decide how much of their time they want to work and how much they want to allocate to leisure activities. Technological progress will increase the farmer's rent (assuming constant prices). The substitution effect will make the farmers work more, since their work is more profitable. The income effect, however, makes the farmers richer, encouraging them to take more free time. Depending on the dominating effect, the farmers will work more or less, shifting the labour-constraint. Therefore pure-yield increasing technologies will have a decreasing effect on deforestation for a subsistence farmer but not for a commercially oriented farmer.

Price effects

[3] The Boserup hypothesis can explain limited adoption of sustainable farm practices which often are labour intensive. Only when land becomes scarce and forest resources are already gone advantages for farmers dominate and adoption begins (Ngoma et al. 2018, Kaimowitz and Angelsen 2008).

Yield increases only lead to an increase in profitability of farming when prices stay constant. But increasing yields raise the supply and therefore can decrease prices. The amount of price increase depends on demand elasticity and on the market share of the sector that is intensifying. For globally traded goods price effects will be low, while prices on a local market will be affected more intensely (Hertel 2012, Ngoma et al. 2018). Therefore the incentive to expand agricultural land is not given when yield increases lead to a decline in prices.

Scale of adoption follows this logic: if many producers adopt a yield increasing technology, then supply increases and prices drop. Hence, yields rise but profits not and forests are spared. Accordingly this can lead to negative effects on local scale but positive, land-saving effects on global scale (Ngoma 2018; Angelsen and Kaimowitz 2001b).

It has been hypothesised that beef price is the main driver over deforestation in the Amazonas region. The so-called "hamburger connection" states that the increased demand for fast food is responsible for shrinking forests (Dávalos et al. 2014). In detail it says that increased international demand for beef raised prices and led to the expansion of pastures.

Governance

Governments have the possibility to control the increase of farm-land. However, in remote areas and forest frontiers state power often is limited. The effect of increased governance can be differentiated between conventional aspects of governance and environmental aspects. Conventional aspects are, for example, corruption control, rule of law, and accountability. An increase in conventional good governance structures does not necessarily have a decreasing effect on deforestation. On the contrary, they can foster land expansion and thus deforestation, since good governance can create a favourable climate for investment (Ceddia et al. 2014). Still, also bad governance increases deforestation. Bulte et al. (2007) show that in Latin America low agricultural yields are connected with deforestation if agricultural subsidies are connected with corruption. According to their model, farmers intentionally chose bigger land sizes with extensive production to receive more government subsidies. In this way, the bigger land sizes foster deforestation.

The picture changes when a focus is given on environmental policies. When good forest monitoring and conservation policies are in place, farmers will rather use the scarce factor land more intensively (Ngoma et al. 2018, p. 184). The consequence for agricultural policies is that technology-driven intensification has to be combined with environmental regulations, such as land-use zoning, economic instruments, strategic deployment of infrastructure, certification and sustainability standards to stall deforestation (Ceddia et al. 2014; Byerlee et al. 2014).

The land degradation-deforestation hypothesis and the land-as-wealth hypothesis describe the connection between property rights and deforestation. The former says that less secure tenure might lead to less investment and to more soil exhaustion (Angelsen 2010, p. 19641). The latter describes a similar situation: land is cleared to facilitate ownership claims. In this case extensive agricultural land use is practiced for the expectation of future value increases and not for the purpose of generating profits from agricultural production (Dávalos et al. 2014).

1.5.7 Win-Win, Win-Lose, Lose-Win, Lose-Lose Scenarios

It has been shown that a farmer’s inclination to expand their territory depends on a number of factors that interact and depend on each other. The variables that were presented here are the input factor intensity of the new technology in combination with the input constraints a farmer faces. Distance to the forest frontier raises the motivation to adopt a labour- or capital-intensive technology that reduces pressure on forests. A farmer’s inclination to maximise their profits increases pressure on forest while subsistence farmers are said to reduce their territory when technology permits them to. New technologies can have price effects depending on the scale of the market and the demand elasticity. Good governance might have a negative effect if it is not combined with strong environmental policies.

It is important to define the time-scale of the analysis. In the short-run many variables are fixed, while in the long-run they become variable. Prices for production inputs and wages are usually not very flexible in the short-run while they will adapt in the long-run (Cattaneo 2001). Accordingly, a technology can bring short term benefits which are reduced over time.

To sum up the former discussion, the resulting scenarios of technology introduction can be win-win, win-lose, lose-win or lose-lose for farmers and the forest (Angelsen and Kaimowitz 2001b). For example, a technology can improve farmers’ livelihoods, increase agricultural yields, and at the same time save forests from deforestation. This is the case when farmers face labour constraints and the technology is labour-intense. However, when massive adoption leads to a decrease in prices for the farmer’s product, their livelihoods will not improve in the long run, while still less forest is used (lose-win). A capital- or labour-saving technology, however, has the possibility to produce a win-lose scenario. Farmer’s livelihoods and yields increase while forest resources are depleted. Last but not least, lose-lose scenarios are possible as well. Prices will adapt over time when a technology is adopted on large scale. The initial profit gains of the early adopter will then disappear. In this case the agricultural land was expanded while benefits for farmers lasted only for a short time.

1.5.8 Empirical Findings on Agricultural intensification and Deforestation

Villoria et al. (2014) compare economic studies on specific technological interventions in agriculture and find a generally weak link between technological progress and land use. Merry and Soares-Filho (2017) try to answer the question whether the intensification of beef production in the Brazilian Amazon will deliver intensification outcomes using a comparative analysis of the historic development of beef production in the US and Brazil. Their results suggest that intensification (not focused on sustainability) will have few conservation outcomes and recommend focusing on credit, land tenure, illegal land use, infrastructure, underlying development incentives and the strengthening of existing protection efforts in order to protect the Amazon. Kaimowitz and Angelsen (2008) compare seven case studies and conclude that improving agricultural technologies will result in more deforestation by making agriculture more profitable. For Silvopastoral Systems, however, they identify a positive short-run effect. Ngoma and Angelsen (2018) study the effect of minimum tillage as a technology of conservation agriculture and its effect on cropland expansion into forests in Zambia. They found no significant effect between adoption and expansion. Dávalos et al. (2014) investigate variables that influence forest loss in Guaviare, Colombia, north of Caquetá. They test the “hamburger connection” versus the Land-as-wealth hypotheses and conclude that demand for beef is not connected with pasture extension.

1.6 Knowledge Gap

Studies have shown that intensive SPS in model farm situations intensify production since milk yields and stocking rates were increased. Sustainability indicators also showed a positive outcome. Accordingly, SPS have the potential of SI. For absolute evidence, however, it still has to be investigated how the technology influences farm outcomes when applied and adapted outside a research environment. This adaptation process might change the benefits of the technology.

Studies already created evidence for the connection between technologies of agricultural intensification and deforestation. Links are seen to be rather low. It still remains to be shown whether a technology that focuses on sustainability (and the value of forests and trees) can prove to have a positive effect in the protection of forests.

1.7 Research Question

The aim of this thesis is to contribute to answering the following question:

Research Question: Does Sustainable Intensification protect forests from deforestation?

To do so, the following sub questions (SQ) will be answered with a focus on SPS in the region of Caquetá.

SQ1: Is farming with Silvopastoral Systems a form of Sustainable Intensification?

This question is answered in two parts: a qualitative part and a quantitative. Qualitative workshop results are used to analyse the sustainability of SPS in Caquetá. The intensification is analysed using quantitative data. Three indicators of intensity are observed and compared between farmers that have SPS and farmers that do not: 1) the milk yield per hectare as output variable, 2) the yearly labour days per hectare as input variable and 3) the stocking rate of animal units per hectare. Additionally the linear distance of farms to the highway is analysed.

SQ2: Do farmers with more intensive production have relatively more forest reserves?

For SQ2 farmers' forest reserves are analysed in a linear regression model. The exogenous variables are the three variables of intensity (of SQ1), the distance and SPS as dummy.

Additionally, for triangulation of quantitative results and to answer the main research question, qualitative data of expert interviews and of a participatory workshop is incorporated into the analysis.

1.8 Expected Results

The expected results for SQ1 are that SPS can be categorised as SI. Therefore it is expected that experts see SPS as sustainable and that annual milk yields per hectare and stocking rates are higher for farms with SPS. Annual labour days per hectare are expected to be higher for farms with SPS as the technology is expected to be labour-intensive (see 1.5.4). Farms with SPS are expected to be located closer to the highway (see 1.5.5).

Under the premise that intensification protects forests the expected results for SQ2 are that SPS, labour days per hectare, annual milk yields per hectare stocking rates and distance all have a positive effect on forest reserves. It is expected however that the results of this study are ambivalent since it is meant to show that a clear statement on the effects of SI on deforestation is not per se possible but a careful analysis of input factors and macroeconomic variables has to be conducted before ex-ante predictions are possible. In order to protect forests the introduction of innovations in agriculture should be surrounded by well reflected regulatory policies.

1.9 Target Group of Research and Contributions to Science

This research is embedded into the research project “Implementing sustainable and livestock systems for simultaneous targeting of forest conservation for climate change mitigation (REDD+) and peace-building in Colombia” (SLUS). This project is led by the International Centre for Tropical Agriculture (CIAT) in partnership with the Leibniz Centre for Agricultural Landscape Research (ZALF) and the Centre for Research in Sustainable Agricultural Production Systems (Cipav). It is funded by the International Climate Initiative (IKI). By evaluating the impact of SPS on deforestation this thesis supports project activity II.17: Ex-post Integrated Impact Analysis of piloted SLUS on key social, environmental, economic and peace building indicators using a methodological framework tool box. The study creates evidence of the effects of the adaptation of a technology by farmers on their intensity of production and on their forest reserves. The results of this study will help policy makers to evaluate the effects on deforestation of up-scaling business models of sustainable land-use in Caquetá and similar regions at the agricultural frontier.

1.10 Structure

The following chapter first introduces the case study region Caquetá. Subsequently, the three data sources (expert interviews, workshop results and a database) are described followed by the data processing and the methodology. The result section is divided into four parts. The first two parts each focus on one sub question, the third part presents regional experts' opinion on the effect of SPS on deforestation generated in a workshop, and the last part presents additional information that was generated in interviews that help to better understand the case. It is divided into information on livestock practices, deforestation, and SPS. After the results section the findings are linked with each other in the discussion in order to answer the research question. This part includes limitations and further research needs that result from this study. Finally the conclusion summarizes the generated knowledge of this work.

2 Material and Methodology

2.1 Case Description

Colombia was chosen as a study case for the following reasons. In its report on Biodiversity for Food and Agriculture the FAO stressed the danger of a declining biodiversity for food and agriculture (FAO 2019). The Amazon Rainforest is an important resource of biodiversity and plays an important role for the global climate (Suarez et al. 2018). It is however endangered by deforestation and climate change. It was recently suggested that at 20-25% deforestation a tipping point might be reached where the hydrological cycle of the Amazon will cease to function and the whole region could flip to a non-forested ecosystem (Lovejoy and Nobre 2018). The Colombian Government has accepted the forest's importance by formulating the vision of zero deforestation (Enciso et al. 2018).

With the signature of the peace-treaty in 2016 between FARC and the Colombian government a period of post-conflict started (Eufemia et al. 2019). The prior 50 years of armed conflict introduced illegal mining and illicit crops, which caused deforestation, while fumigation with glyphosate caused fertility loss and water pollution (Suarez et al. 2018). In the post-conflict period the drivers of deforestation change. Formerly FARC controlled areas face a power-vacuum as sufficient government structures don't exist yet (Revelo-Rebolledo 2019). Economic development creates pressure on natural resources, which translates to a growing rate of deforestation (Eufemia et al. 2019).

Caquetá is Colombia's third largest department[4] covering about a third of the country's total area (Ocampo 2015). The department consists of three landscapes, the eastern flank of the Andean mountains, the foothills ("piedemont") and the Amazon plain (Murad and Pearse 2018). Colonization started in the beginning of the 20th century and received a push between 1960 and 1970 through government funded settlement projects (Dávalos et al. 2016). Population density is very low with about half a million inhabitants (Graser et al. 2020). The department has been described as a hotspot of the armed conflict, and for this reason socioeconomically it is characterized by high rates of poverty, violence and inequality (Chaparro Orozco and López Rodríguez 2017). Tree cover in the department decreased from 1990 until 2014 from 56.4% to 51.6% activities; in 2016 26.544 ha of forests were cleared in the department, which amount to

[4]Colombia is divided into 32 departments (from Spanish: departamento) which build the first-level governmental subdivisions (Law 2015).

14.8% of the national deforestation (Enciso et al. 2018). Deforestation is mainly focused to the agricultural frontier of the department while there are indications that forest cover slightly increased in the western municipalities of the department between 2000 and 2016 where resources are already depleted (Murad and Pearse 2018). Deforestation has been related to the expansion of pastures for livestock activities due to milk production in extensive pasture based systems being the department's main economic pillar and pastures being highly degraded caused by overgrazing and poor management. Therefore the implementation of agroecologic practices such as SPS are fostered in recent years (Landholm et al. 2019).

2.2 Data Sources

2.2.1 SAL-Survey

Data for the quantitative analysis was taken from the database that resulted from a survey which was carried out by the project Sustainable Amazonian Landscapes (SAL)

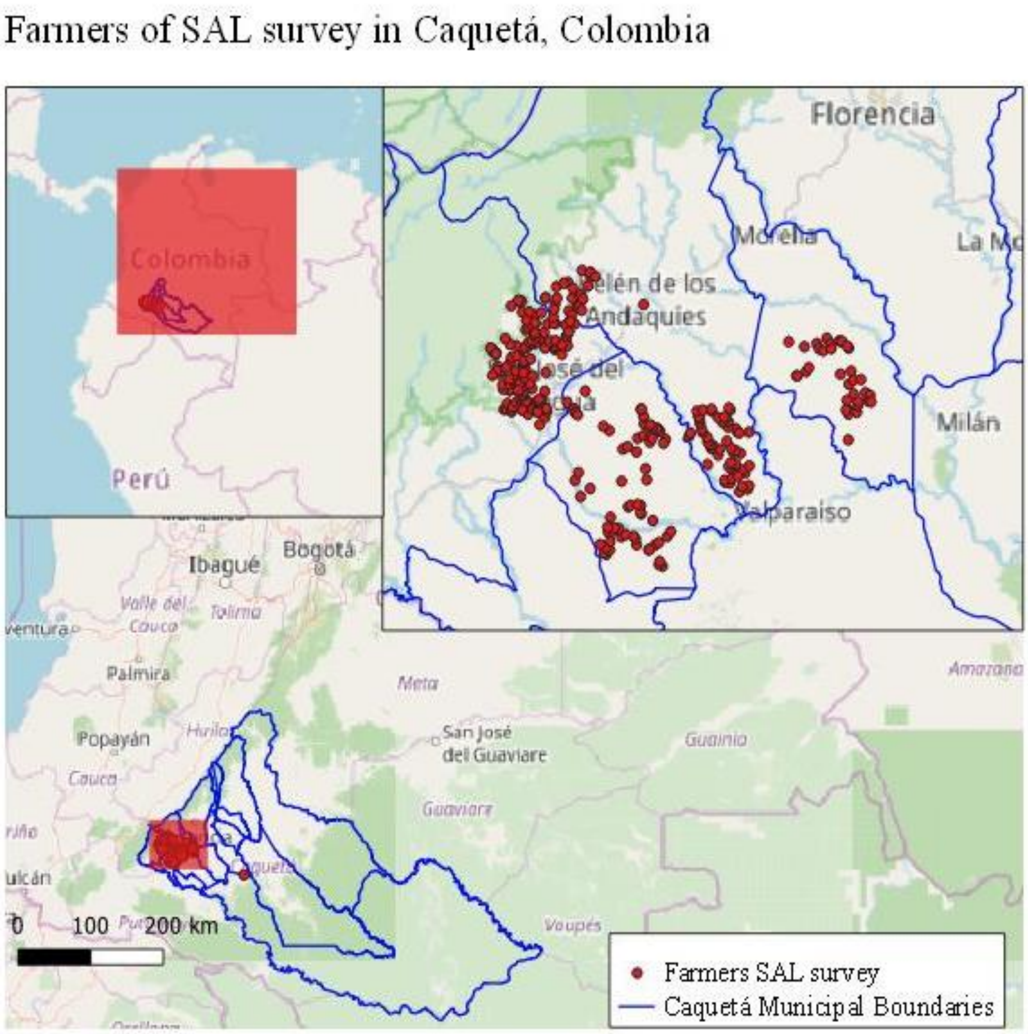

Figure 2: Map of farmers in Caquetá (own projection. base map: OpenStreetMaps)

between March 2016 and October 2016. It contains household and farm data from the four municipalities in the south of Caquetá: Albania, Morelia, Belén de los Andaquíes and San José de Fragua. The sampling process is not known to the author. It was however organised through CIAT and CIPAV, and it is expected that scientific standards were applied. Nevertheless the survey is representative at a municipal level according to the 2005 national census (Landholm et al. 2019). In total 341 farm households were surveyed. The survey contains 14 modules with socio-demographic data, household data, data on natural resource management and data on farm characteristics, among others. In total over 1000 variables were collected. The modules used for this thesis are module H ("Actividades productivas y recursos naturales"), module K ("caracterización de la finca") and module N ("Ganadería"). The variables used and their Spanish description are found in table 1. The geographical locations of farmers are visible in red in Figure 2.

Variable Name	**Section of SAL-Survey**	**Spanish description in SAL-survey**
Modulo H. Actividades productivas y recursos naturales:		
activity	H1	Actividad productiva
purpose	H1_2	Propósito
Modulo K. Caracterización de la finca (K2):		
lat	K1_1_1_1	Finca 1: Latitud
lon	K1_1_2_1	Finca 1: Longitud
landscape	K1_5_1	Finca 1: En qué paisaje se encuentra
area_SPS	K2_7_1	Silvopastoril sin incluir pasto de corte o banco forrajero
area_forest	K2_10_1	Área en bosque
area_pasture	K2_4_1	'Área en pasturas sin incluir las que estan en sistemas silvopastoriles'
area_total	K2_1_1	Área total de la finca
Modulo N3_Inventario_pecuario:		
Heifers breeding: exist	N4_3_7	Novillas Levante (1-2 años): Tiene este tipo de animales?

Heifers breeding: number	N4_4_7	Novillas Levante (1-2 años): cuántos en total tenía en últimos 12meses?
Heifers breeding: average weight	N4_6_7	Novillas Levante (1-2 años): Cuál es el peso promedio del animal? Kg
Heifers bearing: exist	N4_3_8	Novillas Vientre (2-3 años): Tiene este tipo de animales?
Heifers bearing: number	N4_4_8	Novillas Vientre (2-3 años): cuántos en total tenía en últimos 12meses?
Heifers bearing: average weight	N4_6_8	Novillas Vientre (2-3 años): Cuál es el peso promedio del animal? Kg
Young bulls for fattening: exist	N4_3_9	Novillos de Ceba Machos: Tiene este tipo de animales?
Young bulls for fattening: number	N4_4_9	Novillos de Ceba Machos: cuántos en total tenía en últimos 12meses?
Young bulls for fattening: average weight	N4_6_9	Novillos de Ceba Machos: Cuál es el peso promedio del animal? Kg
Female Calves: exist	N4_3_13	Terneras (0-1 año): Tiene este tipo de animales?
Female Calves: number	N4_4_13	Terneras (0-1 año): cuántos en total tenía en últimos 12meses?
Female Calves: average weight	N4_6_13	Terneras (0-1 año): Cuál es el peso promedio del animal? Kg
Male Calves: exist	N4_3_14	Terneros (0-1 año): Tiene este tipo de animales?
Male Calves: number	N4_4_14	Terneros (0-1 año): cuántos en total tenía en últimos 12meses?
Male Calves: average weight	N4_6_14	Terneros (0-1 año): Cuál es el

		peso promedio del animal? Kg
Dry Cows: exist	N4_3_16	Vacas Horras/Secas/escoteras: Tiene este tipo de animales?
Dry Cows: number	N4_4_16	Vacas Horras/Secas/escoteras: cuántos en total tenía en últimos 12meses?
Dry Cows: average weight	N4_6_16	Vacas Horras/Secas/escoteras: Cuál es el peso promedio del animal? Kg
Pregnant Cows: exist	N4_3_17	Vacas Paridas: Tiene este tipo de animales?
Pregnant Cows: number	N4_4_17	Vacas Paridas: cuántos en total tenía en últimos 12meses?
Pregnant Cows: average weight	N4_6_17	Vacas Paridas: Cuál es el peso promedio del animal? Kg
Cows in production: exist	N4_3_18	Vacas en Producción (En ordeño): Tiene este tipo de animales?
Cows in production: number	N4_4_18	Vacas en Producción (En ordeño): cuántos en total tenía en últimos 12meses?
Cows in production: average weight	N4_6_18	Vacas en Producción (En ordeño): Cuál es el peso promedio del animal? Kg
Modulo N7 Mano de obra:		
activity_executed	N12_2	Realiza la actividad?
total_familiy_workdays_man	N12_3_1	Trabajo familiar: Total de jornales por hombres (8h)
total_familiy_workdays_woman	N12_3_2	Trabajo familiar: Total de jornales por mujeres (8h)
total_familiy_workdays_kids	N12_3_3	Trabajo familiar: Total de jornales por niños (8h)
total_contracted_workdays_	N12_4_1_1	Trabajo contratado: Total de

man		jornales por hombres (8h)
total_contracted_workdays_ woman	N12_4_1_2	Trabajo contratado: Total de jornales por mujeres (8h)
<u>Modulo N6 Productos lacteos:</u>		
annual_milk_production	N11_7	Cuál fue la producción anual total leche últimos 12 meses?

Table 1: Variables of SAL-survey used for the quantitative analysis

2.2.2 Participatory Workshop

As part of the project activities of SLUS, on the 14th of November 2019 a participatory workshop was held by a team of ZALF researchers in Florencia, the capital of the department Caquetá. The aim of the workshop was to gather existing knowledge of local stakeholders on the topics collective governance, peace building and sustainable development, to connect stakeholders, and to make knowledge publicly available.

Of the 32 participants, 68.8% came from NGOs, 12.5% were academically employed, another 12.5% came from the public sector and 6.5% were participants from the private agricultural sector. Their main professional focus was agriculture (58.8% of participants), peace building (26.5%) and governance (14.7%). The participants came to 46.9% from urban Florencia, to 25.0% from other municipalities of Caquetá, to 15.6% from rural areas of Florencia and 12.5% worked on national level.

Before the workshop, definitions of key terms were explained to have a common understanding of their meaning. Because of time constraints it was decided not to ask for individual definitions of participants. The term sustainable land-use system was defined as a system of land-use and production that complies with the three pillars of sustainability: the ecological, social and economic perspective (Sotelo Cabrera et al. 2017). For the regional context of Caquetá the following aspects were stressed: the reduction of deforestation, the restoration of landscapes, mitigation of climate change, the construction of peace and the improvement of livelihoods.

For the main workshop methodology a world café was chosen (Aldred 2011). Participants were divided into three panels to discuss three different topics: one set of questions focused on governance, one on peace building and one on the subjects of deforestation, sustainable land-use systems and participatory value chains. After a discussion time of 20 minutes groups switched to the next panel. After two turns every group had discussed all topics. Discussions were recorded and results were noted on posters for the next group to build upon. One participant per panel was assigned to stay fixed to the topic to continuously take notes. Two rounds of world café were performed so that each participant discussed each topic two times: the first time focusing on the present situation and the second time focusing on future perspectives.

This thesis uses material of the panel on sustainable land-use systems and participatory value chains which the author co-moderated. The following materials of the workshop were used for this thesis. 1) Photos of two posters that were created during the panel (see Annex 7.2) 2) the written minutes produced by the participant 3) the audio-recordings. Because of poor acoustics the recordings are usable only in parts. Therefore only parts of the records could be transcribed (used quotes are found in Annex 7.4). The two moderators summarized the results together based on the described material and on their personal conception.

2.2.3 Expert Interviews

During a research trip from September 2019 until November 2019 to the region of focus (Caquetá, Colombia) semi-structured interviews were conducted following an interview guideline (see Annex 7.3). This comprehensive questionnaire was developed by members of the SLUS-project at ZALF. It was applied by all researchers of the SLUS project for their individual research goals. Therefore it focuses on three topics: sustainable land-use, governance and peace-building. In total ten interviews were conducted by the author of which material from four interviews is used for this thesis. The experts were selected based on their knowledge of the regional livestock sector, their experience with SPS and the field of sustainability. Using these criteria the following interviewees were chosen: 1) the president of a regional organization that works with local livestock farmers to disperse SPS, 2) a researcher at UNIAMAZ (Universidad de la Amazonía, Florencia/Caquetá) that worked with farmers in the field of sustainability 3) a master's student of agroforestry at UNIAMAZ that is establishing SPS on his family's farm and 4) the owner of a model farm that started introducing SPS in the year 1999. A table describing all interviews is found in the annex (see 7.1). Interview partners were informed about the purpose of the interviews and signed a letter of consent. The interviews were transcribed. Content analysis was conducted by screening the interviews to find information on SPS in Caquetá and livestock in general (codes: SPS, livestock, deforestation). In a second step the information on SPS was categorised into strength, weaknesses, opportunities and threats (see Annex 7.4).

2.3 Methodology

2.3.1 Methodological Approach for SQ1

2.3.1.1 Sustainability of SPS

In the introduction it was shown that the definition of SI can be divided into the aspects sustainability and intensification (see 1.4). Therefore to answer this question whether farming with SPS in Caquetá is a form of Sustainable Intensification, the analysis is divided into the same two aspects. Firstly it is argued whether SPS are more sustainable than traditional practices by using results from expert interviews and results from the participatory workshop. During the world-café round on present aspects of "deforestation, sustainable land-use systems and participatory value chains" the participants were asked: "Qué acciones se han desarrollado para implementar sistemas de uso de suelo sostenible (SLUS) en los últimos años?" (Which actions have been developed to implement sustainable land-use systems in the last 20 years?). The workshop participants brainstormed actions that were developed in the last 20 years and subsequently voted to order the results from most important to least. To do so, each participant received three glue dots to stick it to their preferred choice. All dots could be added to one option or they could be divided to different options. The results help to answer the sustainability aspect of SPS. Thereafter the intensification is analysed.

2.3.1.2 Intensity of SPS

2.3.1.2.1 Measuring Intensity in livestock farming

Production practices in global livestock production are categorized into pasture-based, mixed and industrial systems (Gerssen-Gondelach et al. 2017). Gerssen-Gondelach et al. (2017) stress that intensification in beef production can be achieved by intensifying within one system (e.g. pasture-based), or by transitioning to a more efficient and more productive system (e.g. from pasture-based to industrial). This study focuses on pasture-based production forms and the intensification within this system. This includes all production forms in which cattle grazes year-round on pastures, diet is mostly based on pasture forage and only a small part of the diet are imported concentrates.

Measuring production intensity is not necessarily a simple procedure. Erb et al. (2013) propose a framework to measure land-use intensity with the three dimensions input intensity, output intensity and associated system-level impacts. They base their framework on initial research from Boserup (1965) and Turner and Doolittle 1978).

Shriar (2000) however accentuates the difficulty of measuring agricultural intensity in frontier regions due to limited data availability, high variability in production and price, and unconventional practices. They discuss different possibilities mostly focused on cropping systems however. The common measurement is output. For cropping systems the cropping frequency and farm unit cropping area [5] can be used as surrogates. Surrogates are necessary to incorporate fallowing practices in cropping systems. This also applies to livestock production in frontier regions; especially when slash and burn methods are applied. In livestock production the stocking rate is commonly used to measure the intensity of extensive livestock production. It is calculated by animal units (AU) per hectare (Landholm et al. 2019) and used to compare the pressure on pasture, for example, or the greenhouse gas mitigation potential. This indicator for intensification has the advantage to be easily measurable. In the study at hand three variables are analysed as measures of intensity: the stocking rate, the annual labour days per hectare for livestock activities and the annual milk yield per hectare.

To evaluate whether SPS is an intensification of livestock farming, the SAL-survey data is used which is panel data. The assumption is made, that more intensive systems are a result of intensification. This is a strong assumption which is further discussed in Chapter 4.4: Limitations.

2.3.1.2.2 Pre-processing and Exploration of Dataset

The analysis is executed in Rstudio using R Notebook. The code for the analysis is found in the annex (see 7.6 and 7.7). As a first step data is cleaned. The original dataset contains data from farms that are located in different landscapes. For this analysis only farmers located on landscape-type 'hills' were chosen in order to be able to assume a similar micro-climate. Also only farmers are analysed that indicated to produce for the purpose of milk or double purpose (milk and meat). The farmers with SPS are defined as farmers that indicated to have at least some area in silvopastoral systems. The logical variable 'silvopastoral' is set to TRUE when variable K2_7 ('Silvopastoril sin incluir pasto de corte o banco forrajero') from section K of the SAL-survey is higher than zero.

Figure 3 shows all farmers on landscape 'hills'. Blue points are farmers that indicated not to have area in SPS, while red points are farmers that indicated to have SPS. Green points indicate missing responses to this question. These are removed from the dataset. The R-output of the summary of the dataset after pre-processing is found in the Annex

[5] Ruthenberg's R: Farm unit area under cultivation relative to total available arable land (Shriar 2000)

(see 7.5). 83 farms are analysed of which 68 don't have SPS and 15 have SPS. Farms without SPS have on average 25.8 animal units and 53.5 hectares of land of which 37.7 hectares are in pasture. The farms with SPS have on average 40.4 animal units and 51.5 hectares of land. Of these 32.4 hectare are in pasture and 3.9 in SPS.

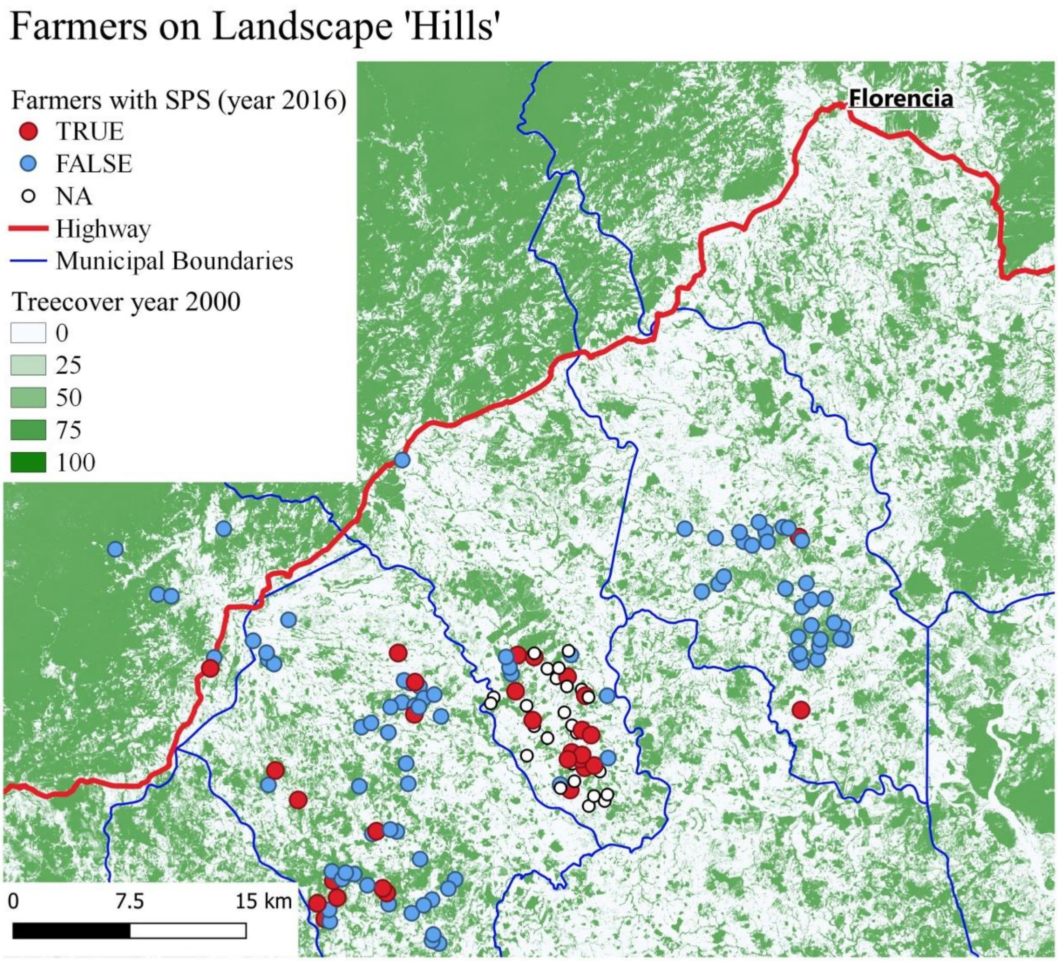

Figure 3: Farmers of SAL-survey on landscape 'hills' (own projection, treecover: Hansen et al. 2013).

Four variables are analysed: 1) the annual milk output per hectare as a variable of output, 2) the annual labour days dedicated to livestock per hectare as a variable of input 3) the stocking rate of animal units per hectare and 4) the distance to the highway. The first three are used as indicators of intensification while the last one is used for the discussion of economic theory. It is assumed that the distance to the highway is highly negatively correlated to the distance to the forest frontier. The means of the variables are calculated for the group of farmers with SPS and for farmers without SPS and compared using two-sided t-tests to see if the Null-hypothesis (difference in mean is zero) can be rejected. The variables are calculated as follows:

<u>Annual Milk Yield per Hectare</u>

The milk output of farmers is calculated using sub module N6 (N6_Productos_lacteos_long.dta") of the SAL-survey. Element N11_6 and N11_7 contain data on daily and annual milk production. To calculate the annual milk yield per hectare, the annual milk production is divided by the sum of the farmer's area in pasture and the area in SPS. The later variables on area expansion are found in section K (K_Caracterizacion_de_la_finca) of the SAL-survey (K2_4 – 'Área en pasturas sin incluir las que estan en sistemas silvopastoriles' and K2_7 – 'Silvopastoril sin incluir pasto de corte o banco forrajero'). Higher values of milk yield per hectare indicate a more intensive production.

<u>Annual Labour Days per Hectare</u>

Information on the farmers' available labour days are taken from model N7 (N7_Mano_de_obra_long.dta). Farmers indicated if they performed a certain activity and indicated how many days per year were dedicated to this task. The table is filtered for activities related to livestock (application of vaccinations, feeding of animals, upkeep of meadows, milking, cleaning animals, cleaning stables, other activities). The labour days per year for livestock are calculated summing up family work hours (of men, women and children) and contracted work (of women and men) of each activity. Labour days per hectare are then calculated by dividing total labour days by the area in pasture and the area in SPS. High values may indicate labour-intensive production.

<u>Stocking Rate</u>

The stocking rate indicates the number of animals that graze on a hectare. The number of animals however is not directly comparable as the impact of the different animal classes (calves, heifers, bulls, cows) differs. To facilitate comparison different methods have been developed. According to Jahnke (1982, p. 9) Tropical Livestock Units (TLU) are calculated using the average weight of each animal. 1 TLU equates to 250 kg of animal live weight. Others propose a factor for each animal class (0.01 TLU for one chicken, 0.1 TLU for one goat, 0.7 TLU for one Cow, Ghirotti 1993). Landholm et al. (2019) use Animal Units (AU) for their analysis, where 1AU equals to 450kg of average animal weight. This latter measurement is applied in this analysis.

AU are calculated by using module N (N_Ganaderia) of the SAL-survey which contains data on average weight, class of animal (calves, heifers, bulls, cows in production etc.)

and number of animals. The column “number of animals” did not contain zero-values. Therefore a mistake during data collection was assumed and missing values were set to 0 animals. Average weight (in kg) is multiplied by the number of animals in each class and divided by 450kg. Summing up the result of all classes resulted in the AU of each farmer.

To calculate stocking rates Landholm et al. (2019) use AU divided by area of pasture plus area of forests because farmers supposedly reported that animals use forest areas for grazing and as heat relief. This information could not be verified and doesn’t seem plausible for this analysis. If farmers used forests for grazing then forests would already be a form of SPS and the differentiation in the survey would be meaningless. The stocking rate is used here as a measure of intensification of pasture systems. Therefore the stocking rate was calculated by dividing AU by the sum of area in pasture and area in SPS.

<u>Distance to highway</u>

In this section a fourth variable is analysed which is not a variable of intensification. As shown in the framework (see 1.5.5) theory suggests that there is a connection between intensification and distance to the forest frontier. Because of the geographic conditions of Caquetá it is assumed that distance to the highway is negatively correlated with distance to forest frontier.

Location data of the farms in the SAL-survey is analysed using QGIS (open source development, qgis.org, version 3.10.2 - A Coruña). Section K of the survey (K_Caracterizacion_de_la_finca) contains latitude (K1_1_1_1) and longitude of the farms (K1_1_2_1). Vector data of the main highway in Caquetá that runs from north to south through the capital Florencia is downloaded from OpenStreetMaps using the plugin QuickOSM. The lines of the highway are transformed into points. Using the tool ‘distance matrix’ the linear distance from the farms to the closest point on the highway is calculated and exported to a CSV.-file to be used in Rstudio.

Figures 4 and 5 show a first visualization of the data (see 7.6.1). A scatterplot of annual milk yield per hectare and distance and a scatterplot of annual labour hours per hectare and the stocking rate are displayed. The green points are the farmers that have SPS. According to the expectations farmers with SPS should have lower distance, higher milk yields per hectare, higher stocking rates and higher labour per hectare than farmers without SPS. Therefore in figure 4 green points should be located rather in the lower right half of the figure compared to the red points. In figure 2 green points should be located in the upper right half of the figure compared to red points. No clear clusters are visual however. Already now it doesn't seem probable that both groups of farmers differ in the measures of intensity. Additionally regarding intensities, it was expected to see more intense production closer to the highway as land should be available more costly. Therefore a negative linear relation between distance and milk yield per hectare was expected in figure 4. For Figure 5 a linearly increasing relation between stocking rates and labour days was expected, as more animals per hectare should mean more labour requirements per hectare.

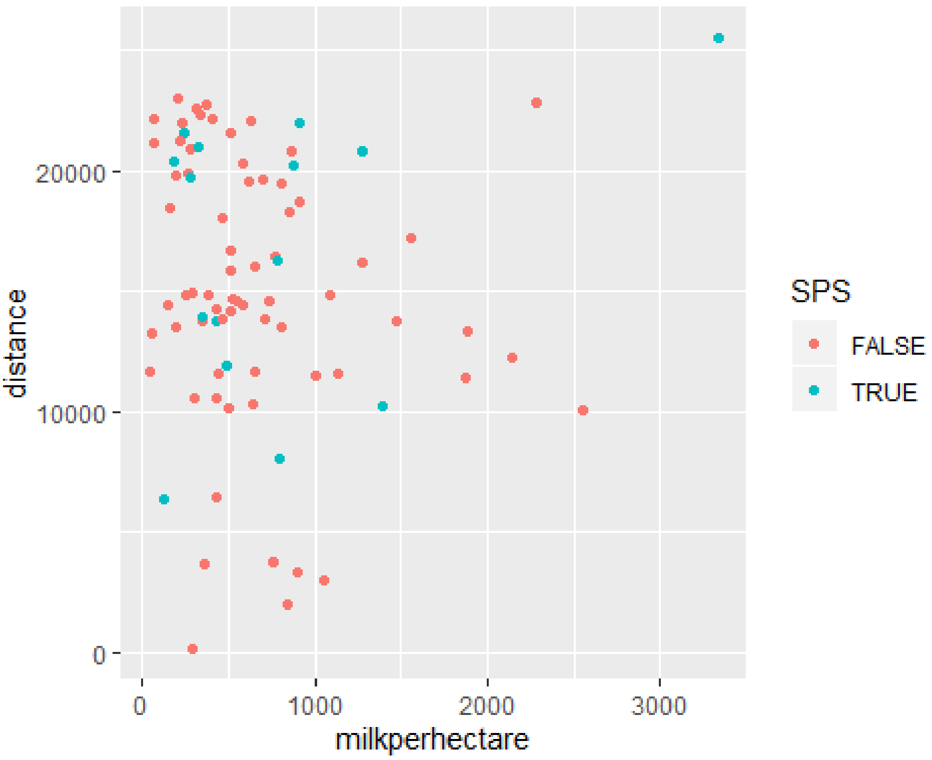

Figure 4: Scatterplot of annual milk yield per hectare and distance (own projection)

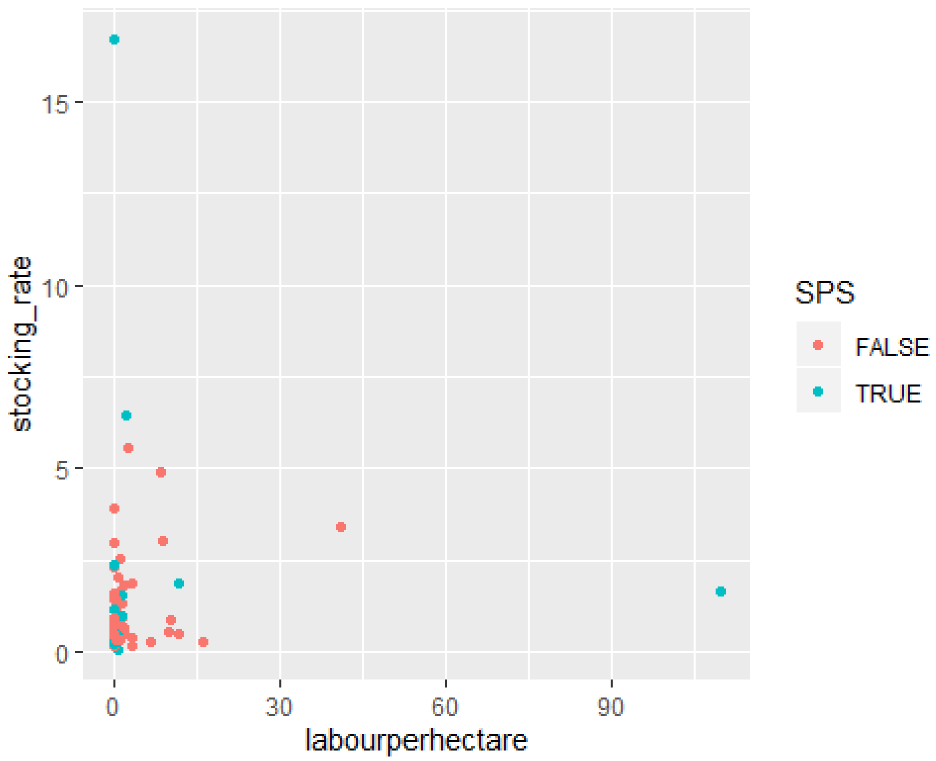

Figure 5: Scatterplot of stocking rates and annual labour days per hectare (own projection)

Histograms and Q-Q plots (quantile-quantile plots) of all four variables analysed are created (see stocking rates: 7.6.2 figure 14, annual milk yields per hectare: 7.6.8 figure 17, annual labour days per hectare: 7.6.14 figure 20, distance: 7.6.20 figure 23). The histograms display the frequency of each value while the Q-Q plots display the theoretic quantiles of the normal distribution against the actual sample quantiles. Both visualizations are used to compare the shape of the distribution of a sample. A normal distribution corresponds to a symmetric bell shape in the histogram and to a linear line of dots along the black line in the Q-Q plots. Plots are displayed for farmers with SPS as well as without SPS. The T-test assumptions are independent observations, normal distribution and metric values (Kim 2015). The examination of the plots reveals skewed distributions of milk yields, labour days and stocking rates. Therefore these variables are log-transformed to reach a normal distribution of observations. Milk yields and stocking rates are transformed using y = log(x). Labour days are transformed using y = log(x+0.01), because zero values exist that would be transformed to infinitive values in the standard log transformation. To compare the distribution of the transformed variables, histograms and Q-Q plots are created again (see 7.6.4 figure 15 , 7.6.10 figure 18, 7.6.16 figure 21). The histograms of the transformed variables display a clearer bell-shape and the Q-Q plots a straighter line than before, therefore a normal distribution of the log-transformed variables is assumed.

In the following step boxplots of all four variables are created (see stocking_rate.log: 7.6.5 figure 16, milkperhectare.log: 7.6.11 figure 19, labourperhectare.log: 7.6.17 figure 22, and distance: 7.6.21 figure 24). The boxplots are separated for farmers with and farmers without SPS. The thick line in the middle of the box displays the median, the outer ends of the box display the first and the third quartile. The vertical lines above and below the box measure 1.5 times the interquartile range (the distance between the first and the third quartile). The interquartile range is often used as a measure of outliers in univariate spaces. In that case every data point further away is considered an outlier. The boxplots allow for a quick comparison of medians and variations of farmers with and without SPS. It is expected that the medians for farmers without SPS are lower than for farmers with SPS for log-stocking rates, log-milk yields per hectare and for log-labour days per hectare. The median for distance should be located higher four farmers without SPS. The boxplots show however that only the log-stocking rates correspond to the expectations. Medians of per hectare log-milk yields and log-labour days seem to be a little higher for farmers without SPS and the distance is very much lower for farmers without SPS.

2.3.1.2.3 Testing

A two-sided t-test is performed to compare the means of the log-milk yields, log-labour days, log-stocking rates and distance (see 7.6.6, 7.6.12, 7.6.18, 7.6.22). The t-test tests whether the means of both groups of farmers (with and without SPS) differ significantly. The Null-hypothesis states that both means are the same. Accordingly when the Null-hypothesis is rejected it can be expected that both means are not the same.

After performing the t-test, the means of the log-transformed variables are transformed back to level values. Because of the log-transformation, the resulting means are the geometric means not the arithmetic means (Feng et al. 2013).

2.3.2 Methodological Approach for SQ2

2.3.2.1 Pre-processing and Exploration

It was shown before (Chapter 1.5) that it is not clear yet how intensification affects forests. Theory and numerous studies have indicated the relevance of different factors.

To generate knowledge on the behaviour of farmers in Caquetá the difference in their individual forest reserves is analysed. The indicator relative forest reserves is therefore defined as a farmers forest area divided by their total area. The variables K2_10 (‘Área en bosque’) and K2_1 (‘Área total de la finca’) are taken from the SAL-survey.

The necessary libraries and the dataframe si.df are loaded into Rstudio. The package “psych” is used to visualize the variables in a convenient way. Histograms, scatterplot and correlations of forest reserves, stocking rates, annual labour hours per hectare, milk yield per hectare and distance are displayed in Figure 6.

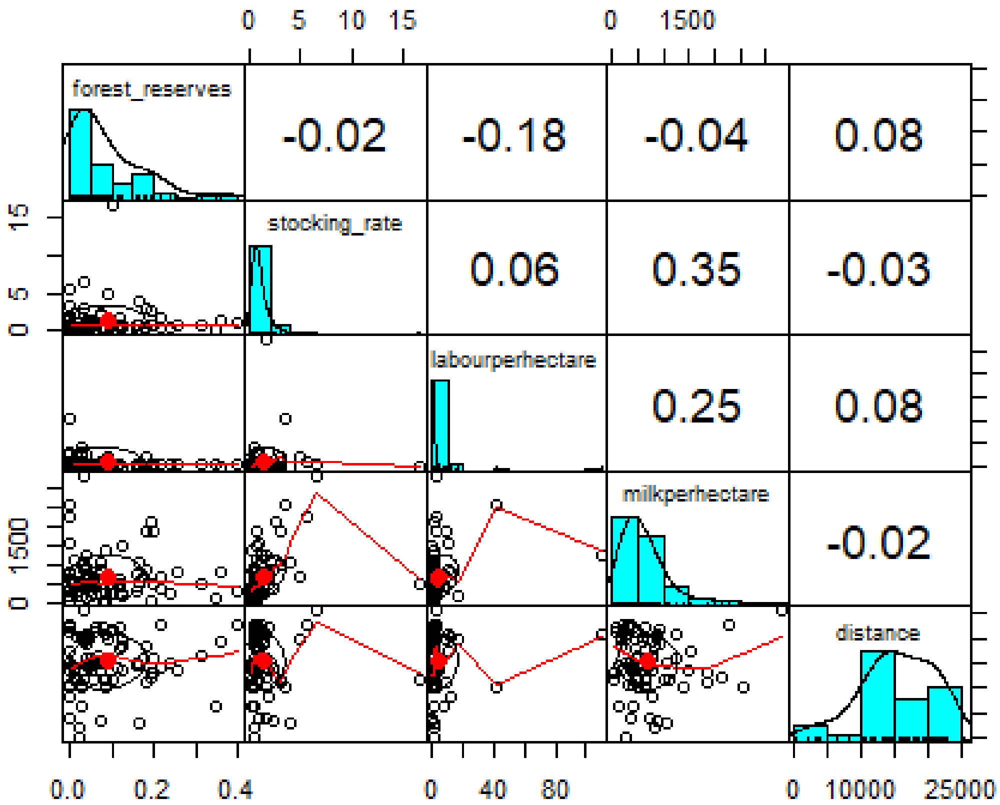

Figure 6: Scatterplot and correlations of forest reserves, stocking rates, annual labour days per hectare, annual milk yield per hectare and distance (own projection)

As the assumption for linear regression is normally distributed data and the histograms in figure 6 show skewed data, forest reserves, stocking rates, annual milk yield and annual labour days per hectare are log transformed to reach more normally distributed variables. Forest reserves are transformed using y=log(x+0.01) to avoid infinitive values. The other variables were already transformed for SQ1. Scatterplots and correlations of log-transformed variables are visualized hereafter in figure 7. Histograms of transformed data show a more normally distributed curve. Other than expected the correlations between forest reserves and the other variables are almost zero. The multiple regression will show whether a combined effect of the variables exist.

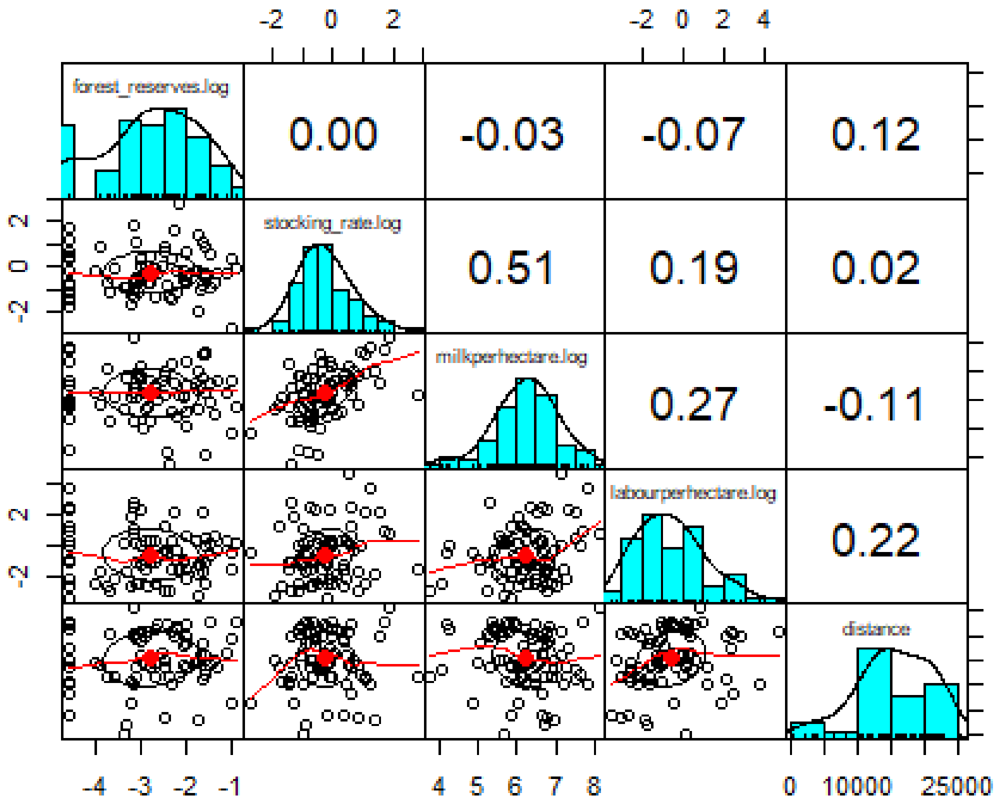

Figure 7: Scatterplots of log transformed variables and distance (own projection)

The detection of outliers is conducted to identify unusual observations that deviate from the behaviour of the other observations (Ghorbani 2019). In univariate spaces box plots and the interquartile range are often used. In multivariate spaces the Mahalanobis distance can be applied which measures the standard Euclidean distance of each point to the mean of the distribution. It is unitless, scale-invariant and includes correlations (Filzmoser 2004). Applying this measure allows to detect observations that behave unusual in at least one variable in comparison to the other variables. The cut-off distance is chosen subjectively after observing the data points. It is assumed that these specific observations are outliers because of errors during the collection of data, during processing or that their production processes differ from the rest in a way that make them incomparable. This could be, for example, a newly established farm that had a lot of labour input invested in the last year but does not produce yet accordingly.

To detect and remove outliers the Mahalanobis distance is calculated (see 7.7.5). It is calculated based on the three variables of intensification: annual milk yield per hectare, annual labour days per hectare and stocking rates. This is based on the assumption that economically and physically there is a connection between these variables. For example, with certain production methods it is assumed that it is not possible to keep 15 animal units per hectare. By excluding outliers, potential flaws in data collection are excluded and rather homogenous farms in relation to production method are analysed. The Mahalanobis distance is added to the dataframe si.df and a logical variable is created. After observation of the Q-Q plot (theoretical chi square quantiles to Mahalanobis distance, see 7.7.6 figure 25) outliers are defined as mhlnbs > 5.5. At this point there is a visual cut in the distribution of observations. The scatterplots (Figure 8, figure 9 and figure 10) show the Mahalanobis distance on the y axis. The horizontal line displays the boundary of mhlnbs = 5.5. The x axes of the respective figures show annual labour days per hectare, annual milk yields per hectare, and stocking rates. Conventional farmers are displayed on the upper half and SPS farmers on the lower half of each figure. Eleven outliers are identified of which four are farmers with SPS. The observation reveals that for example data point G32 supposedly has a very high stocking rate, a standard milk yield per hectare but almost no labour input. It is questionable whether this is physically possible. B25 similarly has very high milk yields per hectare with very low labour. The key-variables of the identified outliers are displayed in the annex (see 7.7.8). Subsequently the outliers are removed from the dataframe.

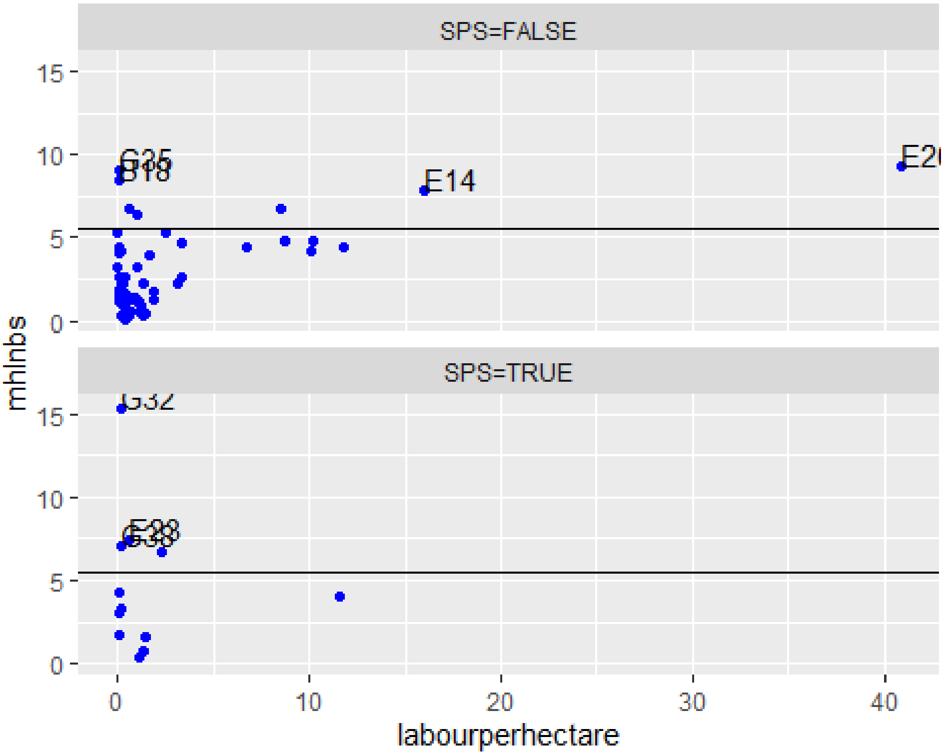

Figure 8: Scatterplot of labour days per hectare and Mahalanobis distance (own projection)

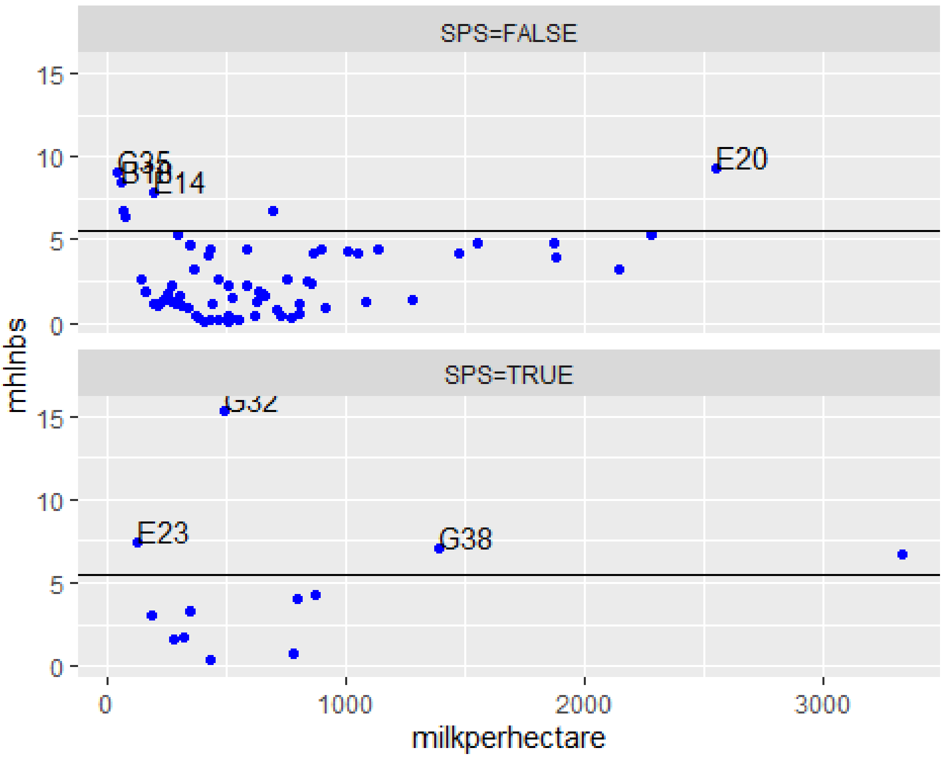

Figure 9: Scatterplot of milk yield per hectare and Mahalanobis distance (own projection)

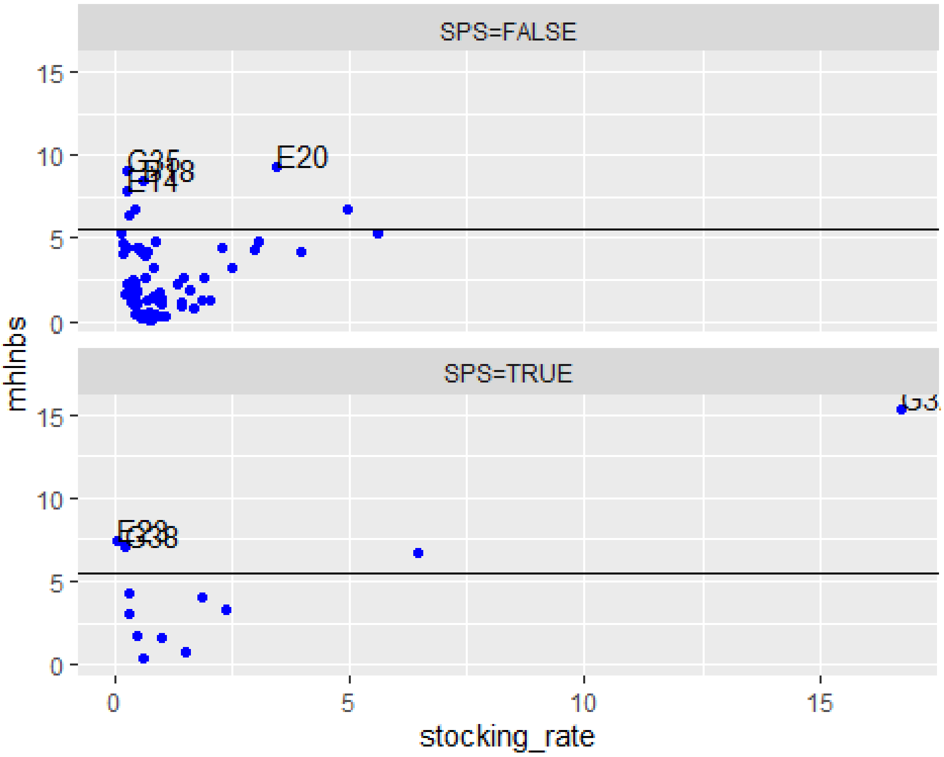

Figure 10: Scatterplot of stocking rate and Mahalanobis distance (own projection)

2.3.2.2 Modelling

A multiple linear regression model is build where forest reserves depend on the variables stocking rate, annual labour days per hectare, annual milk yield per hectare, distance and SPS as a dummy (see 7.7.11). Based on the theoretical framework (see 1.5) it is expected that these variables influence forest reserves.

Subsequently the model is optimized by using the step-function in r (see 7.7.13). The function repeatedly excludes variables from the linear model and calculates the AIC (Akaike information criterion) of the new models. By comparing the AIC an optimal model is found where AIC is lowest. The function dfbeta is then used to compare the effect of individual observations on the estimators (see 7.7.15).

As a final quantitative step it is tested whether farmers with SPS have more forest reserves than farmers without SPS. The means of log-forest reserves of farmers with SPS and farmers without SPS are compared using a one-sided t-test (see 7.7.18). The boxplot of log-forest reserves is displayed in figure 11. Contrary to the expectation, the mean of log-forest reserves of farmers with SPS lies much lower than of farmers without SPS.

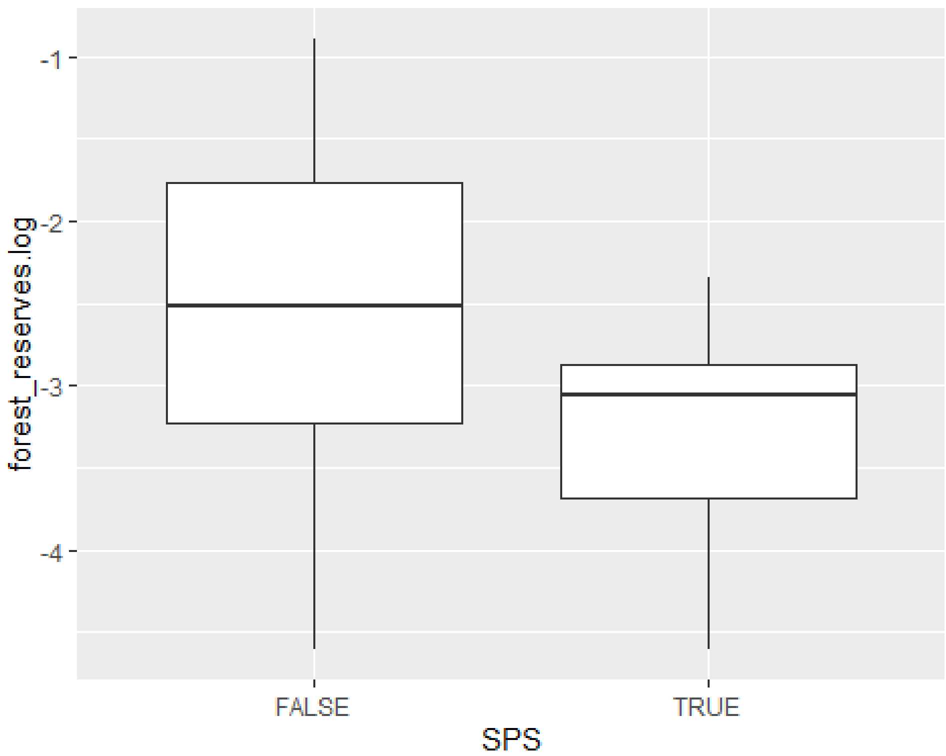

Figure 11: Boxplot of log transformed forest reserves (own projection)

2.3.3 Experts' Opinions on the Main Research Question and Case Update

To triangulate results the opinions of practitioners in Caquetá is compared. Therefore results of the participatory workshop are used, precisely the results to the following question: "Qué efectos tienen los Sistemas Silvopastorales en detener la deforestación?" (Which effects do Silvopastoral Systems have in stalling deforestation?). Quotes are displayed to represent the main conceptions among experts and practitioners in the region. Additionally, expert interviews are analysed according to the codes livestock, deforestation, strengths of SPS, weaknesses of SPS, opportunities of SPS and threads of SPS. This information helps to contextualise the findings of the quantitative results and to update knowledge on the case of livestock production and especially SPS in Caquetá.

3 Results

3.1 To SQ1: Are SPS a Form of Sustainable Intensification?

3.1.1 Sustainability of SPS

Results of the participatory workshop on governance, peace building, and sustainable development can give indications of the sustainability of SPS. Participants were asked: “Qué acciones se han desarrollado para implementar sistemas de uso de suelo (SLUS) sostenible en los últimos años?” (Which actions have been developed to implement sustainable land-use systems in the last 20 years?). The results are summarized in Table 2. In total 12 actions were brainstormed and 31 votes were casted. The development of agroforestry systems was voted the most important action to implement sustainable land-use systems in the region of Caquetá in the last 20 years. It received 12 points. The development of SPS was voted on the second place together with the establishment of protected areas (SINAP – Sistema Nacional de Áreas Protegidas) and the PDET (Programas de Desarrollo con Enfoque Territorial[6]). Each received 3 points. The results of the workshop indicate that regional experts in Caquetá see SPS as a sustainable production form.

Action	Votes
S. Agroforestal	12
S. Silvopastoriles	3
Areas Protegidas (SINAP)	3
Programas de Desarrollo con Enfoque Territorial/PDET	3
Esquema de ordenamiento territorial (EOT) y Plan de ordenamiento territorial (POT)	2
Planificación Predial Participativa	2
Others (6)	6
Total	31

Table 2: Results of Participatory Workshop (Which actions have been developed to implement sustainable land-use systems in the last 20 years?)

3.1.2 SPS as Intensification

The results of the t-tests of means are summed up in Table 3 (see 7.6.6, 7.6.12, 7.6.18, 7.6.22). T-tests were performed for log-stocking rates, log-annual milk yields per hectare, log-annual labour days per hectare and distance to highway for farmers without

[6] A government program that was established to stabilize and transform the Colombian territories that were most affected by the violent conflict

area in SPS and for farmers with area in SPS. The results show that the means for each variable generally were lower for farmers without SPS. A closer look to the p-values however reveals that results are not statistically significant at the 95 % level. The lowest p-value is 0.3 for distance, the highest even 0.9 for labour days. This means that the Null-hypotheses cannot be rejected: it cannot be said with certainty that the means of the selected variables are actually not the same for farmers without SPS and for farmers with SPS.

Variable	**T-value**	**Degrees of Freedom**	**p-value**	**Mean of log-values without SPS**	**Mean of log-values with SPS**	**Level-transformed mean of farmers without SPS**	**Level-transformed mean of farmers with SPS**
Stocking rates	-0.48	16.2	0.6	-0.29	-0.11	0.75	0.90
Annual milk yields per hectare	-0.41	20.3	0.7	6.20	6.30	492.80	545.20
Annual labour days per hectare	-0.13	17.9	0.9	-0.58	-0.50	0.55	0.60
Distance to highway	-1.05	20.2	0.3			15 056	16 772

Table 3: Results of t-test of means of log-stocking rates, log-milk yields, log-labour days and distance to highway

3.2 To SQ2: Do Farmers with More Intensive Production Have Relatively More Forest Reserves?

A multiple linear regression model is built to model the effect of key-variables on forest reserves (see 7.7.11). The chosen variables are log-stocking rate, the log-annual milk yield per hectare, the log-annual labour days per hectare, the distance to the highway and the dummy variable SPS.

<table>
<tr><th></th><th>Estimate</th><th>Std. Error</th><th>t value</th><th>Pr(>|t|)</th><th>Significance</th></tr>
<tr><td>(Intercept)</td><td>-0.41</td><td>0.1697</td><td>-2.44</td><td>0.02</td><td>*</td></tr>
<tr><td>Log-stocking rates</td><td>0.0112</td><td>0.0195</td><td>0.57</td><td>0.57</td><td></td></tr>
<tr><td>Log-milk yields</td><td>0.0112</td><td>0.0243</td><td>0.46</td><td>0.65</td><td></td></tr>
<tr><td>Log- labour days</td><td>-0.0030</td><td>0.0089</td><td>-0.33</td><td>0.74</td><td></td></tr>
<tr><td>SPS=TRUE</td><td>-0.0725</td><td>0.0403</td><td>-1.80</td><td>0.08</td><td>.</td></tr>
<tr><td>distance</td><td>+0.0000</td><td>+0.0000</td><td>2.01</td><td>0.049</td><td>*</td></tr>
<tr><td></td><td colspan="5">Significance Levels: * = 0.05, . = 0.1
Multiple R-squared: 0.1038, Adjusted R-squared: 0.03264
F-statistic: 1.459 on 5 and 63 DF, p-value: 0.216</td></tr>
</table>

Table 4: Model statistics of linear regression

The model statistics show positive signs for the estimates of log-stocking rates, log-milk yields and distance (see table 4). Labour days and SPS have negative signs. Except for distance none of the variables are significant at the 95% level. Still, the estimate of distance is almost zero and therefore the effect on forest reserves is very small. SPS is significant at the 90% level. R-squared is 0.10 and adjusted R-squared 0.03. The adjusted r-square value is extremely low; therefore the explanatory power of the model is low as well. The f-value is 1.46 with a p-value of 0.216. The result shows no significance for the F-statistics at the 5% level. It therefore is not possible to say that the exogenous variables have a combined effect on the forest reserves.

Variable selection is performed in order to optimise the model. The original model has an AIC of 12.83 (see 7.7.13). After stepwise exclusion of variables the new model has an AIC of 7.99. The exogenous variables of the new model are SPS and distance.

<table>
<tr><th></th><th>Estimate</th><th>Std. Error</th><th>t-value</th><th>p-value</th><th>Significance</th></tr>
<tr><td>Intercept</td><td></td><td>0.0364</td><td>-9.2</td><td>0.000</td><td>***</td></tr>
<tr><td>SPS=TRUE</td><td>-0.0731</td><td>0.0392</td><td>-1.9</td><td>0.067</td><td>.</td></tr>
<tr><td>Distance</td><td>+0.0000</td><td>+0.0000</td><td>1.9</td><td>0.062</td><td>.</td></tr>
<tr><td></td><td colspan="5">Significance levels: 0 = *** , . = 0.1
Multiple R-squared: 0.08861, Adjusted R-squared: 0.06099
F-statistic: 3.209 on 2 and 66 DF, p-value: 0.0468</td></tr>
</table>

Table 5: Model statistics of optimised linear model

The optimised model shows a small negative effect of SPS and a positive but almost zero effect of distance (see table 5). The significance for each of the exogenous variables however shows only at the 90% level. At the 95% significance level the Null-hypothesis therefore cannot be rejected. Multiple R-squared is 0.089 and adjusted R-squared is 0.06. The explanatory power is still small but increased in comparison to the original model. The f-value of the new model is 3.21 with a p-value of 0.047. Therefore the Null-hypothesis that the combined effect of both variables on forest reserves is zero can be rejected. The calculation of the model is repeated multiple-times leaving out single observations each time. The results show that the signs of the estimators change repeatedly (see 7.7.15). This indicates that single observations have a great effect on the model.

Variable	**T-value**	**Degrees of Freedom**	**p-value**	**Mean of log-values without SPS**	**Mean of log-values with SPS**	**Level-transformed mean of farmers without SPS**	**Level-transformed mean of farmers with SPS**
Forest reserves	2.46	13.3	0.01	-2.72	-3.37	0.06	0.02

Table 6: T-test results of mean log-forest reserves of farmers without SPS and farmers with SPS

The one-sided t-test of log-means of forest reserves shows a p-value of 0.01 (see table 6). Therefore farmers without SPS have significantly higher forest reserves than farmers with SPS. On average the former have only 3% of their total area in forest while the latter have on average 6% of their total area in forests.

3.3 Experts‘ Opinion on the Effect of SPS on Deforestation

The participants of the participatory workshop were asked how they evaluate the effect of SPS on stalling deforestation (“Qué efectos tienen los Sistemas Silvopastorales en detener la deforestación?”). The results help to discuss results of the quantitative analysis.

Most participants agreed that SPS does not directly affect the deforestation rate of primary forest: *“Que no servía para no deforestar las zona que hay acutalmente forestales, pero si servía para reforestar las zonas que han sido deforestados”* (taller 2, #00:38:02-3#). They argued that SPS is rather a technology that is applied in already established farms were forest resources are mostly depleted: *“Los sistemas silvopastoriles los estoy haciendo generalmente a partir de ganaderías consolidadas. Cuando yo tengo un ganadero de muchos años que ya tiene prácticamente todo su predio deforestado. [...]Así él no sigue deforestando zonas de bosque en otras* *territorios."* (taller 2, #00:38:02-3#) The positive effect of SPS was stressed that the system gives farmers a productive base. For this reason farmers don't have to give up their farms and move further into the forest frontier.

One participant however saw the potential that, by reducing the plot size necessary for one animal, more forest would be spared: *"claro que contribuyen a detener la deforestación, porqué el área es más pequeña y se tiene más ganado. Entonces no van necesitar deforestar otro espacio más grande, porqué ya tenemos más ganado y nos alcanza... Ese espacio se va reduciendo y aumenta en carne y leche. Y no va aumentar en ganado. [...] Claro que es una manera en detener la deforestación!"* (taller 2, #00:48:13-4#) As another positive effect of SPS it was highlighted that the system creates a new secondary forest in already established zones. This creates habitats and wildlife corridors. Furthermore it was mentioned that the diffusion of SPS can have an indirect positive effect because it teaches farmers the value of trees in the agroecologic system which would prevent farmers from further clearing forests: *"La gente que implementa sistemas silvopastorales tienen más sensibilidad ambiental. La familia va valorar lo que es un árbol y ya no va a tumbar más bosque para formar potreros."* (taller 2, #00:39:35-3#) Close attention should be given to the design of SPS because their effect differs for example depending on the varieties of trees: *"Depende al sistema silvopastoral porqué hay sistemas que realmente no contribuyen tanto a la reforestación. […]"* (taller 2, #00:42:48-4#). One participant raised the concern that in the long-run SPS will foster deforestation if it relies on precious woods. They reasoned that these trees will be cut for market after a certain lifespan contributing to deforestation: *"Los sistemas silvopastoriles son de corto plazo porqué seguramente en 20 años el campesino va a cortar los árboles cuando pueda venderlos. (...)"* (taller 2, #00:49:16-7#).

3.4 Case Update: Results of Expert Interviews

3.4.1 Livestock

Experts acknowledge the continuing relevance of extensive cattle ranching for the regional economy of Caquetá. New cultures such as cacao or pisciculture are being introduced, but they don't come close to the economic importance of livestock. Farmers that introduce new cultures usually only have it as a small secondary branch (encuesta 3, #00:04:56-0#, #00:32:03-2#; encuesta 7-3, #00:00:15-7#). Reasons for the continuing importance of livestock are first traditional but also economic. Even though livestock production is not very profitable the sale of milk offers a steady cash flow that continuously supports the livelihood of farmers. Farmers receive payment every two weeks for their milk, the so called "quincena" (encuesta 3, #00:31:24-6#), while for crop cultures this period can be at least three month: "*Mientras que la ganadería... la leche... usted recibe un cheque quincenal, y este cheque le permite al campesino y al productor comprar la remesa. Los otros cultivos son a varios meses, dos meses, tres meses. Entonces el productor no tiene un flujo de caja para poder mantener las actividades de la finca y para comprar sus remesas. Eso es lo que ha permitido que la ganadería se mantenga en el tiempo en el Caquetá." (encuesta 6-2, #00:23:18-2#)*

Missing entrepreneurial attitude is described as a fundamental problem among farmers: *"Primo la visión! La gente no mira la finca como una empresa.[…]Va ser muy difícil que salgan adelante. Porqué si tu no miras la finca como una empresa tu no vas a generar ingresos económicos!"* (encuesta 6-2, #00:32:06-8#). As a consequence they are not able to generate profits. This is based on a lack of current knowledge: *"no tienen conocimientos actuales, tecnologías actuales, técnicas, aprendizajes, conocimientos que pueden servir."* (encuesta 6-2, #00:32:06-8#). Farmers receive traditional knowledge about farm practices from their ancestors which is not adapted to the problems that agriculture currently faces. Traditional farm practices that are not adapted to tropical conditions lead to degradation processes. As a consequence average stocking rates are as low as 0.5 animal per hectare (encuesta 4, #00:02:44-6#; encuesta 6-2, #00:00:04-4#)

Apparently however a change in attitude is already observed by experts. While in the past people valued to own a maximum of animals, now profitability and animal health start receiving more importance: "*El cambio es que ya la gente están entendiendo que no debemos tumbar más montas y aprovechar lo que tenemos, ser más productivos, ser más eficientes. Eso es lo que ya la gente está entendiendo. Que por decir algo aquí una persona era feliz diciendo que tenía 300, 400 reses. Ordenar 100 vacas y sacar 100 litros de leche! Ya se dio cuenta que es mejor tener 20 vacas y sacar los 100 litros de leche que tener esas 100. Menos va contaminar, menos va acabar con el suelo. Y va ser más rentable!"* (encuesta 7-2, #00:05:47-2#)

Lack of qualified labour seems to be a problem for livestock producers: *"la mano de obra falta"* (encuesta 3, #00:26:29-9#). On the one hand not enough profit is generated to pay workers, on the other hand workers lack skills to be of help on the farm: *"El sistema productivo no es tan altamente eficiente como para contractar mano de obra* *para trabajar en la finca. O hay veces que escasea la disponibilidad de mano de obra cualificada. Porqué hay gente que tu la contratas pero pues no es como muy capacitada para eso. Va hacer un trabajo mal hecho entonces todo se va a caer.”* (Encuesta 3, #00:27:21-0#)

3.4.2 Deforestation

Experts agree that Caquetá currently is one of the hotspots of deforestation (encuesta 4, #00:05:18-5#). Slash and burn practices are part of the traditional farm practices and are an important driver of deforestation in the region (encuesta 4, #00:02:44-6#). The practices are passed on from generation to generation: *“Es cultura del departamento, porque el departamento fue colonizado! Entonces por decir algo yo, mi papá entró y tumbó montaña, y eso me enseñó a mi! Tumbé montaña, y yo le enseñé a mis hijos!”* (encuesta 7-2, #00:06:17-9#) Traditionally forest is burned in the dry season between December and January. When the rain starts in March pasture is sown which in june is ready for cattle: *“Las tumbas en el departamento del Caquetá son principalmente en los meses de diciembre e enero, en las epocas secas. Para que en febrero esté quemando y cuando entren en marzo las lluvias, pues ya usted puede regar el pasto. El pasto germina en dos meses [...]. En julio lo que era antes bosque ya es pastura.”* (encuesta 3, #00:12:27-0#).

The peace treaty of 2016 between national government and the FARC-guerrillas resulted in an increase of the deforestation rate in Caquetá. Before the guerrilla was controlling and taxing deforestation by collecting the so called “vacuna”: “*Ellos* [la guerrilla] *cuidaban y protegian esa parte. Cierto? Y el campesino le tiene pavor, le tiene miedo a esta gente. entonces ellos decían: ‘No hay que tumbar montaña’. Nadie tumbaba un palo. ‘Hay que cuidar esa agua!’ Listo! Los que cultivaban coca: ‘No hay que tirar estes residios de la coca al agua!’ Listo! Hicieron pozos sépticos, hicieron todo eso. Ahora que ya ellos han soltado algo de mando en las regiones entonces está volviendo la tala, se está volviendo a ver el desorden en esa parte.”* (encuesta 7-2, #00:05:29-6#) With the retreat of the guerrilla farmers started to expand their territories again (encuesta 4, #00:03:45-9#).

The interview partners were ambiguous about the main source of deforestation. Some were convinced that big enterprises finance deforestation: *“El problema que existe actualmente es que dicen los campesinos que ellos no tienen la capacidad de tumbar, osea el problema no son los pequeños campesinos, sino que el problema son las* *empresas grandes que venden madera. Las empresas grandes lo que hacen es invertir en maquinaria para hacer tala de muchisimas hectarias de bosque. Ellos talan 200, 100 hectarias de bosque en uno o dos meses. Porque ellos cuentan con la herramienta para hacerlo. Un campesino no tiene la herramienta, solo puede tener una sierra y cortar unos tres arboles al día. Una empresa con maquinaria puede tumbar muchismo. Entonces eso es uno de los conflictos."* (encuesta 4, #00:06:14-6#) Others think that smallholder agriculture keeps being the main source: *"Primero inician los pequeños, son los que comienzan deforestando, colonizan."* (encuesta 6-2, #00:02:06-5#).

The problem of degradation through unsustainable farm practices fosters deforestation. Areas where agriculture has been practiced for decades are described as "zones of consolidation". These zones experience degradation and desertification. Farmers in these regions that cannot support their farm any longer sell their land and move further into the forest to build a new farm: *"Lo que pasa es que la zona de consolidación sí existe. Es una zona donde la ganadería ya es vieja. Y en esta zona ya la tierra está más degradada. Y en algunos casos esta tierra pasa procesos de desertificación. Los niveles de lluvia disminuyen y los pastos, si no hay agua, son poco productivos. [...] Por eso esa gente busca nueva finca. Nueva finca o nuevos territorios para colonizar y tener más tierra."* (encuesta 6-2, #00:01:42-0#)

3.4.3 SPS

3.4.3.1 Strengths of SPS

Introduction of SPS in the region started around the year 2000. Since 2010 efforts of distribution were intensified (encuesta 6-2, #00:13:55-4#). The described benefits match the literature (see 1.3). According to an interview partner it is possible to sustain a profitable silvopastoral system on only five hectares which would make SPS especially interesting for small farmers (encuesta 4, #00:19:08-9#). The interview partner was convinced that SPS raise the economic sustainability of production and foster an entrepreneurial way of thinking (encuesta 6-2, #00:03:32-8#). This is due to the regeneration of soils (encuesta 3, #00:22:34-9#). Additionally, depending on the variation of SPS, it is possible to generate supplementary income through the sale of wood (encuesta 4, #00:52:20-9#). The trees generate shadow which increase the wellbeing of the animals and offer habitat for wildlife. This increases biodiversity (encuesta 3, #00:22:34-9#). Finally the system also helps to mitigate climate change through carbon capture of trees (encuesta 6-2, #00:03:17-5#).

"Es una alternativa para el departamento. Porqué aparte del confort del ganado, la sombra. El ganado cuando está en mejor confort con más sombra, reduce la temperatura. El ganado se comporta mejor. El rendimiento productivo es mayor cuando hay bienestar del animal. Y por el otro lado también se mitiga mucho que el sol pegue tan fuerte directamente en la tierra. […] Creo que de una o otra manera termina beneficiando la ecología del sistema y por otro lado termina beneficiando la economía del productor. Y creo que las personas que implementan los sistemas silvopastorales tienen mayor sensibilidad ambiental, porque dicen 'mi tierra antes era puro sol, mucha temperatura. Ahorita está mejor, mi tierra ha mejorado. Hay que cuidar el medioambiente.' Y ellos empiezan hacer división de potreros. Comienzan a pensar cómo pueden producir más. Ya solucioné el problema de la temperatura, ahora como puedo producir más? […] Comienzan hacer otra serie de cosas que valen al sistema silvopastoril." (encuesta 4, #00:05:11-0#)

3.4.3.2 Weaknesses of SPS

One interviewee stressed the difficulty of establishment as well as the upkeep of SPS. A newly established SPS on an area of land cannot support animals for up to two years. This constitutes a high investment cost for many farmers: *"implementar eso lleva tiempo y es muy costoso porque[…] adecuar un hectaria te costaría dejar quieto eso uno o dos años [...]. Entonces el campesino no tiene toda ese área para dejar un área quieta, improductiva [...]"* (encuesta 3, #00:18:37-1#). Upkeep is difficult as well, because a lot of labour is necessary for maintenance: *"mantener un sistema silvopastoril, yo creo no es tanto el establicimento sino el mantenimiento. […]* (encuesta 3, #00:20:09-1#). As labour seems to be scarce the additional labour need for SPS is hard to spear for farmers: *"Pero ahí el mantenimiento es lo más duro, porque para el agricultor empezando lo duro es mantener su unidad productiva y mantener lo otra que cuesta [incomprehensible] el mantenimiento de las cercas. Entonces todo eso le genera mucho desperdicio porque especialmente los campesinos o los productores del departamento ahorita hoy en día la mano de obra es muy limitada*." (encuesta 3, #00:22:34-9#).

3.4.3.3 Opportunities of SPS

Two interviewees shared the view that SPS support in stalling deforestation. They argued that the distribution of SPS would change the traditional mind-set of farmers. According to them the traditional view is to deforest to increase the amount of cows.

SPS however would show the farmers that it is possible to increase stocking rates instead of pasture size (encuesta 7-2, #00:05:07-7#). There are indications that the traditional attitude of farmers is changing to a more sustainable way of thinking even though it is still predominant (encuesta 7-3, #00:05:43-9#). Farmers would start to appreciate the value of forests and care more about healthy animals than about the number of animals (encuesta 7-2, #00:05:07-7#). They also stressed that SPS creates a secondary forest that can be counted as reforestation. *"[...] digamos que si se implementan los sistemas silvopastoriles, si se detiene la deforestación porque ellos van a cambiar la concepción de tumbar el bosque para ingresar más vacas, porque aquí el pensamiento es que si yo voy a comprar una vaca más necesito tumbar un hectárea para esa vaca. Entonces con los sistemas silvopastoriles va sobrar espacio. [...] Sí, es una forma de frenarlo porque cambia esa cultura de tumbar para ingresar más animales por un lado, y por el otro lado si el bosque secundario no es tan importante como el primario pero si se llega a reforestar pues sería maravilloso, no?"* (encuesta 4 #00:19:08-9#)

Opportunities are seen in the research of local species to lower costs of establishment and have better adaptation to local conditions: *"...dejar especies que son nativas del departamento que pueden ser potenciadas en sistema silvopastoriles, por lo menos actualmente los que crecen muy fácilmente son Guayabos y Limones, el Mandarino que le dicen actualmente acá y otros que les dicen Arrayan, hay variedades de aceitunas, hay unos arbolitos que se comportan muy bien y que uno va dejando en los potreros y se van adaptando bien."* (Encuesta 3, #00:19:52-0#) The method of so called "ecological succession" was mentioned to establish a SPS with low costs. In this method a plot is deforested and when trees come out again they are left standing to build a SPS over time: *"Si, porque es mejor. Digamos que usted va a tumbar un cañedo en un proceso [incomprehensible] sucesión ecológico, puedes tumbar todo y puedes quemar pero ahí retornan, entonces uno va dejando disperso los arboles importantes, y van siendo un arboles dispersos, un sistema silvopastoril de árboles dispersos. Pero hay gente que fumiga todo y solo deja pastura, entonces una va haciendo [incomprehensible] unos árboles, arboles muy bueno, [incomprehensible] otro, otro, otro... ya. Y después cuando ya estén grandes, comienza la poda para que entre la luz y cuando ya hay muchos árboles, pues hago un raleo y mantengo... hago un silvopastoril que no me ha costado tanto, que yo tengo que hacer un semillero para... o algo [incomprehensible] que por lo menos te dona las plantas."* (encuesta 3, #00:25:16-6#)

3.4.3.4 Threats of SPS

So far not enough knowledge has been created about adapted SPS to local conditions. The fear was expressed that the systems that are currently being distributed will fail after a few years because species are not adapted to local conditions or will attract pests: *"Yo pienso que se necesita hacer más investigación porqué los sistemas silvopastoriles que se han implementado hasta el momento han sido con especies foráneas de la Amazonía. Melina, Leucadena, Llopo, una serie de especies que no son nativas de la Amazonía. Y eso genera un problema porque la gente piensa que ha implementado sistemas silvopastoriles con cacao, y con plátano, pero el plátano no es el de acá, y el cacao tampoco es de acá. Pues dicen que es por generación de ingresos... Pero esas especies no son nativas del sitio y por tanto en algún momento traen consecuencias sobre el suelo y se vuelve insostenible. Lo que posiblemente vendemos como un idea muy sostenible al futuro nos vamos a dar la cuenta que no fue sostenible porque al suelo se la acabó la materia orgánica. Y de pronto el cacao chupó todo el potasio, el nitrógeno y el fósforo al mismo tiempo. Y que el cacao no hace simbiosis con la rizosfera y no hace simbiosis con ciertas bacterias de la Amazonía. [...]"* (encuesta 6-2, #00:17:37-9#) (see encuesta 3, #00:22:34-9#, #00:23:23-0#, #00:25:16-6#)

3.5 Summary of Results

Practitioners in the region of Caquetá see SPS as a more sustainable production form compared to traditional methods. However, it could not be demonstrated yet that farmers with SPS produce more intensively than farmers without. As well, it was not possible to show whether the stocking rate, the annual milk yield per hectare and the annual labour days per hectare have an effect on farmers' forest reserves. It was shown however that farmers with SPS on average have less forest reserves than farmers without SPS. The participants of the participatory workshops were ambiguous about the effect of SPS on deforestation. Many practitioners don't seem to see a direct link between SPS and deforestation as suggested by economic theory but rather emphasize the reforestation potential, as well as long term indirect effects such as ecologic awareness of farmers and increased economic sustainability. These results are discussed in the following section.

4 Discussion

4.1 SQ1: Are Silvopastoral Systems a Form of Sustainable Intensification?

This study divides SI into the two aspects sustainability and intensification, and looks at SPS from these both angles separated from each other. The literature suggests that SPS improve a number of indicators of sustainability such as reduced soil compaction, provision of wildlife habitats, increased biomass production, and reduced greenhouse gas emissions among others (see 1.3, Solorio et al. 2017; Landholm et al. 2019; Rivera-Herrera et al. 2017). To investigate the sustainability of applied SPS in Caquetá the study consulted experts' opinions through material gathered in a participatory workshop and semi-structured interviews with experts. Participants of the workshops and interview partners were NGO-fieldworkers, governmental employees, researchers and agricultural practitioners that are familiar with the local conditions in the region of Caquetá. They have experience with the regional application of practices, can make comparisons between different farms, and can interpret changes in land-use over a longer time-scale. SPS were seen by the participants of the participatory workshop as the second most important action that has been implemented to develop sustainable land-use systems. It is worth mentioning that the action voted on first place was the development of agroforestry systems and that SPS are a form of agroforestry. The differentiation that practitioners seem to make is that they see agroforestry as focusing on the combination of crops with shrubs and trees while SPS focuses on livestock activities instead of crops. In this light it can be deducted that SPS in Caquetá can be seen as increasing the sustainability of livestock production.

When looking at a certain indicator, the picture becomes less clear however. Before the workshop a sustainable land-use system was defined to have a regional focus on the reduction of deforestation, the restoration of landscapes, mitigation of climate change, the construction of peace and the improvement of livelihoods. Similar to this definition's incorporation of the reduction of deforestation, many definitions of SI ask that agricultural intensification is achieved without the expansion of agricultural area (Pretty and Bharucha 2014). By this definition a technology that increases agricultural area cannot be SI. In contrast, when discussing the effect of SPS on deforestation, many regional experts were not convinced that SPS has a diminishing effect on the deforestation rate of forests. An interview partner even described a local adaptation of SPS, “ecological succession”, which was described as being constructed from a newly burned down forest to construct a low-cost SPS from local tree varieties (see 3.4.3.3). It cannot be assumed that this form of SPS helps to diminish deforestation if the prerequisite for this system is to clear forest. Then again the view exists that SI can be achieved in two-ways: 1) SI through land-sparing and 2) SI through land-sharing (Lerner et al. 2017). Land-sparing intensifies agricultural production on part of the land and conserves the other part. In contrast, in land-sharing the production method itself can increase production while offering environmental benefits. Among experts the view exists that established SPS constitute a new secondary forest. Therefore SPS could contribute to SI through a land-sharing approach if not through land-sparing. As a result, it depends on the definition of sustainability and on the definition of SI whether SPS can be rated as SI, precisely on whether an improvement or non-deterioration of all indicators of sustainability is expected or whether trade-offs are accepted.

The intensification aspect in SPS was investigated by comparing the means of three variables of intensity of farmers that manage SPS and of farmers that do not manage these systems. The significance of the differences in means was tested by applying the t-test. The three variables of intensity are 1) the stocking rates, which indicate how many animals a farmer keeps on their pastures and on their SPS, 2) the annual milk yield per hectare and 3) the annual labour days that are invested into livestock per hectare. The literature suggests that SPS increase the stocking rate up to 3.8 times together with increasing milk and meat yields per hectare up to 5 times. At the same time the technology is said to be more labour intensive. Therefore it was expected that all variables of intensity would be higher for farmers with SPS.

The results of the means of all three values were higher for farmers with SPS than for farmers without SPS which gives weak indications that the expectations are actually true. Unfortunately however it was not possible to reject the Null-hypothesis for all three variables. Therefore it cannot be said with certainty that the results could be repeated if data would be collected again with new random samples from the same area.

A few reasons can be named, that results are not significant. Firstly the farmers with SPS only have limited area in SPS. On average farmers with SPS had only about 10 percent of their area that is dedicated to livestock production (pasture + SPS) in SPS. Therefore farmers with SPS are not “pure” SPS-farmers. Improvements in variables of intensification therefore mix with conventional practices. For example, the milk yield is only known for the farms in total and not independently for cows on SPS and cows on extensive pasture systems. Secondly, the age of the establishment of SPS was not considered in the analysis. It was stated by interview partners that SPS need some time to unfold their benefits. During this time capital and labour are bound; the pay-off period does not start until a certain point. The idea of SPS is fairly new in the region of Caquetá and environmental consciousness is just starting to spread. It can be expected that a few of the surveyed farms with SPS are currently not yet harvesting the fruits of the investment into SPS. Thirdly, not all input factors could be observed. Capital input in the form of machinery, pesticides, herbicides and fertilizers could not be incorporated because of 1) missing data and 2) the complexity of comparison. Possibly the SPS farmers produce the same yield with less chemical inputs which would also be a form of SI.

In summary it could not definitively be proven that SPS applied in the field is a form of SI according to all definitions. Even though literature, experts, and quantitative results indicate the potential of intensification as well as of the systems sustainability, more research is necessary to give an absolute answer.

4.2 SQ2: Do Farmers with More Intensive Production Have Relatively More forest Reserves?

The study investigated whether there is a relation between key-variables and the amount of forest that a farmer owns in relation to their total land size. The investigated variables are the stocking rate, the annual milk yield per hectare, the annual labour days per hectare, the distance to the highway, and whether a farmer has SPS or not. Two multiple regression models were built. The first model includes all variables. It has very low explanatory power, and it cannot be rejected that all exogenous variables have no effect at the same time. Especially the chosen variables of intensification do not show significance. The signs of the estimates of log-stocking rates and log-milk yields per hectare were positive suggesting higher forest reserves with more intensive production. The estimate of log-labour days per hectare has a negative sign suggesting lower forest reserves for more labour-intensive production. The signs are the opposite of what the framework based on Angelsen and Kaimowitz 2001 suggests. The authors propose that intensification usually leads to an expansion of agriculture. More labour-intense production on the contrary is proposed to decrease agricultural land. This view, however, cannot be supported by this study as the variables of intensification do not show to be significant in the multiple regression and the signs of the estimates were opposite of what was expected.

After stepwise optimisation based on the AIC the variables of intensification were removed. The second optimised model finds significance of the variables distance to highway and the dummy SPS, but only at the 90 per cent level. The p-value of the f-test is lower than 0.05 suggesting that both estimates are not zero at the same time. The sign of SPS is negative suggesting that farmers with SPS on average have lower forest reserves. This was confirmed through a t-test. Distance to the highway has a positive sign but the estimate is very low; close to zero. The explanatory power of the model was increased but remains very low.

The theoretical framework based on Angelsen and Kaimowitz 2001 suggests that farmers reduce their agricultural area as a result of technological change under the following circumstances (among others): 1) when the technology is labour-intense and 2) farmers face labour constraints, 3) when farmers are subsistence farmers. The interviewed experts gave indications that all three conditions apply in the case of SPS in Caquetá: 1) SPS needs more labour than traditional pasture systems, 2) labour is a scarce factor as skilled labour is either not available or not affordable and 3) farmers lack of an entrepreneurial attitude, which can be interpreted as farmers are predominantly subsistence oriented. Under these conditions it is expected that with the introduction of SPS a farmer would decrease their agricultural land, at least once the SPS are established and start to pay-off. Therefore it was expected that farmers with SPS would have a higher ratio of forests to total land compared to other farmers. On the contrary, however, it was found that on average farmers with SPS have significantly less forest reserves than farmers without SPS.

The framework presented in this study suggests causality between intensification and deforestation. Therefore the conclusion could be made that farmers with SPS have less forest reserves as a result of intensification and therefore SPS lead to an increase in deforestation. It could however not be shown that farmers with SPS actually have a more intense production and therefore this conclusion seems not to be valid. Additionally, the quantitative analysis made the implicit assumption that all farmers started with the same initial forest endowments. But farms are heterogeneous and start with different carrying capacities (the amount of animals a hectare of land can sustainably support) and amounts of forests. Therefore an alternative hypothesis is suggested based on the Boserup hypothesis (see 1.5.5). According to Boserup (1965) a farmer will only start exploiting the intensive margin once extensive margins have already been depleted. In the discussed case this would mean that farmers depleted their resources by means of traditional production forms until expansion of land was no longer possible or too costly. Only at this point more intensive production forms such as SPS become economically interesting for the farmer. This suggests a reverse causation where deforestation causes intensification. This relation is supported by statements of experts as well as by literature. Expert during the participatory workshop stated that they see SPS as a technology for farms in consolidated zones that already depleted their natural resources. The findings of Murad and Pearse (2018), who found a slight increase in tree cover in the consolidated zones of Caquetá between 2000 and 2016, can be interpreted as a support of the former proposition. Furthermore, it goes in line with the predictions of Culas (2012), who estimated an inverted U-shaped environmental Kuznets curve for Latin America, indicating that with increasing per capita income tree cover will first decrease and then increase again.

Distance to the highway was shown to be significant in the optimised regression model with a very low but positive sign of the estimator. This result suggests that the further away from the highway a farm is located the higher are its forest reserves. Intuitively this makes sense because the further a farmer is located from the highway the closer it is to the forest frontier. Closer to the forest frontier settlement is younger and sparser and therefore more forest patches still exist. On the contrary, closer to the highway, colonization processes started already many years ago. The regional experts call this zone “consolidated” zone. Here, forest reserves are expected to be smaller, because the process of expansions of pastures, due to soil degradation, has been going on for a while. The result of the regression confirms this. Nevertheless the estimator is close to zero, indicating that this effect is very small. A reason for this could be that the farms in the SAL-database are located in a quite small area around the highway. The furthest measured distance of a farm is only about 20 km away from the highway while pastures reach more than 200 km into the direction of the rainforest (measured in GoogleMaps).

Mean distance did not differ significantly between farmers with SPS and farmers without SPS. Based on the Boserup hypothesis it was expected that farmers closer to the highway would rather intensify production using labour-intensive technology than farmers located further away from the highway. This could not be confirmed. The mean distance of farmers without SPS was actually a little less than of farmers with SPS. This fact could as well be founded in the limited area of farms in the SAL-survey compared to the total distance to the forest frontier. Probably in this distance range there are different reasons that are responsible for the distribution of SPS among farmers. When looking at the location of SPS-farmers (see 2.3.2.1 figure3) different spreads of SPS from municipality to municipality are visible. Therefore it is probable that other factors than distance are responsible for the distribution of SPS. Innovation theory could possibly be more insightful at this scale.

In summary, to answer this sub question, this study did not find that farmers with more intense production have more forest reserves. In general it did not find an effect of intensity on forest reserves. On the contrary it found indications that the amount of forest reserves could determine a farmer's tendency to establish sustainable production technologies.

4.3 Answering the Research Question: Does Sustainable Intensification Protect Forests from Deforestation?

The result of this discussion can be summed up as to that whether SI protects forests remains a question of definition. Some definitions of SI incorporate non-expansion of agricultural area as prerequisite and therefore SI protects forests per definition. When relaxing this condition this study argues that SPS have the potential of SI, but a measurable protection effect on deforestation of SPS and therefore of SI could not be shown on a farm-scale. Studies have postulated before that the link between intensification and deforestation is weak (Villoria et al. 2014). The results at hand suggest that a focus on sustainability in intensification does not change this picture immensely.

The potential of macroeconomic and long-term effects of SPS to reduce deforestation was raised by experts, however. Among them are the improved economic sustainability that reduces the need of farmers to sell their land and move to the forest frontier, as well as the potential to increase ecological consciousness. These were not a focus of this study design and are discussed in the following chapters on limitations of this study and further research needs.

At this point it needs to be said that it cannot be expected that SPS, or methods of SI as such, will by their nature solve the problem of high deforestation rates in the Amazonian region of Colombia. It has been emphasized by other studies before, that intensification must be accompanied by strong regulatory measures in order to reduce deforestation (see 1.5.6 on Governance, Ngoma et al. 2018; Byerlee et al. 2014; Ceddia et al. 2014). Ceddia et al. (2013) differentiate between conventional and environmental aspects of governance and argue that the former can have a negative and the latter a positive effect on the reduction of deforestation. The interview partners indicated that, through the retreat of the guerrilla after the peace-treaty, especially the control of environmental regulations declined in the region. For these reasons the role of governance of natural resources to protect forests in Caquetá cannot be underemphasized.

4.4 Limitations

This study is subject to a number of limitations which are described hereafter. The reason for these limitations is mostly based on the fact that the region of focus is a remote area that is hardly accessible by non-local scientists. Even after the peace treaty of 2016 predominant parts (except for the regional capital Florencia) remain prone to the emergence of local conflicts. Research can only be executed with the incurrence of personal risks by the scientist. The available data therefore is still limited and has to be based on regional experts and secondary data sources. The main quantitative data-source for this study was the SAL-survey executed in 2016, which to this point remains the most recent available data-source with a regional scope. The hope remains that in the future the situation will soothe and more detailed research will be rendered possible.

The fact that data is limited has the following consequence:

1. Sustainability: Firstly, when discussing the sustainability of SPS in Caquetá, expert's rating of different actions was consulted. If quantitative farm data of different sustainability indicators were available the discussion could have been more detailed and trade-offs between indicators could have been better evaluated.
2. Intensification: Two limitations can be named in concern of the intensification measures of this study. Firstly, to analyse intensification the intensity of different farms was calculated. The assumption was made that more intense production is a consequence of intensification of production. Intense production

however can be a consequence of different factors. For example, a newly cleared plot will support more animals than an older plot as degradation of soils will only be noticeable after a certain time of utilization. To gain a better understanding of intensification processes, the use of time series data instead of panel data is recommended to have the possibility to evaluate effects over time on individual farms instead of comparing farms among each other that have very different preconditions (Shriar 2000). Secondly, the discussion of the effect of intensification was based on three variables of intensity and the variable distance. Additionally, the farmer's characteristics were incorporated through deduction from experts' statements on entrepreneurship. The theoretic framework however names more factors that theoretically influence deforestation and were not analysed more closely. Especially capital intensity shall be named as it can affect the sustainability of a technology and the intensification. Because of the need for monetization, the analysis is especially difficult however, as farm gate prices of capital inputs have to be known for comparison of capital inputs. Other factors mentioned are price effects and governance. The last factor seems especially relevant in the case of Caquetá, as the change of governance through the peace treaty and the retreat of the guerrilla had an enormous effect on deforestation according to the literature and experts.

3. <u>Forest Reserves:</u> The choice of forest reserves entails three limitations. Firstly, no information about the initial endowment of forest reserves of farms before intensification was available. Therefore the assumption needed to be made that all farms start with the same endowment. With time series data this limitation could be resolved. Secondly, the indicator of forest reserves entails that deforestation is only observed on a farm level. It was mentioned however by experts that deforestation through pasture expansion is as well caused by migration of farmers to the forest frontier. This macro effect is not analysed. Lastly, slash and burn practices are part of the traditional form of livestock production in Caquetá. Through the definition of forest reserves as it has been done in this study, it is assumed that all forest a farm possesses is primary forest. Slash and burn practices on the other hand could mean that there are on-going processes of clearing and regrowth.
4. <u>SPS</u>: Different SPS exist that are expected to have different effects on sustainability, intensification, and on deforestation. Furthermore SPS need a

certain time of establishing. High variation in labour days per hectare are an indicator that farms with SPS might be in different stages of establishment, which could explain the limited significance of results. The limited data base did not allow for a closer differentiation among systems according to time of establishment of SPS or kind of SPS.

5. Geographic scope of study: As a further point, the general scope of this study is focused on a relatively small area of the region of Caquetá. Participants of workshop and experts are mainly from Florencia and adjacent municipalities, and the farms of the SAL-survey are located in a small part of the south-west of Caquetá that is relatively close to the highway; the farthest distance of a farm was around 20 km away. This zone was described as consolidated by experts. It is expected that, because of the huge distances, economic realities differ enormously in the department, especially when comparing the consolidated zone with areas located closer to the forest frontier that partly are only reachable by boat.

4.5 Further Research Needs

The results of this study together with the afore mentioned limitations raise the need of further research to further shed light on the connection between deforestation and the sustainable intensification through SPS. Mostly the need to generate more precise data exists. Further needs are the following:

- More information should be generated on how SPS applied by farmers affect sustainability indicators to evaluate which trade-offs between indicators exist. Therefore a closer look should be given to the different systems, how farmers apply them, and whether farmers adapt systems to local conditions that perform especially well in these indicators. Especially interesting seems to be the research of the system of “ecologic succession” which seems to be a cost-saving adaptation with local tree-species that could entail negative consequences on deforestation, as has been discussed before.
- In this context, the reasons of farmers to establish SPS should be investigated further. Experts claimed that SPS would have a positive effect on deforestation, because it would change the attitude of farmers towards the environment and trees. Whether this is the case and whether this actually motivates farmers to refrain from deforestation remains to be proven.

- To generate more knowledge of the intensification potential of SPS, of the trade-offs with sustainability, and of the effects on deforestation, the capital-intensity of farmers in Caquetá should be closer investigated and compared with labour-intensity and yields per hectare. To avoid the problem of monetization, a Data Envelopment Analysis (DEA) could be applied as has been suggested by Gadanakis et al. (2015).
- A better understanding of the intensification of production through SPS and the effect on forest reserves can be generated through the generation of time series. Researchers at UNIAMAZ currently investigate a number of farmers from the SAL-survey with regular visits since 2016. Should the generated data be published, a better understanding of processes on individual farms will be possible.
- Forest reserves were analysed in relation to stocking rates, where forest reserves are defined as the ratio of forest area to total area, and stocking rates are defined as animal units per area dedicated to livestock (area in pasture + are in SPS). This design implicitly focuses on a land-sparing approach. SPS has the potential of being qualified as SI when applying the land-sparing approach, because SPS create new secondary forest. In this light, the quantitative analysis should be repeated with forest reserves defined as the ratio of forest area and area in SPS divided by total land area. In this way the created secondary forest would be counted as part of the forest reserves of a farmer. As a consequence, however, potentially primary forest would be valued the same as secondary forest under production. Nevertheless, the reforestation potential of SPS would be appreciated through this approach. It would be interesting to see whether this approach leads to farmers with SPS still having significantly less forest reserves than farmers without SPS.
- The scale of the study should be broadened to incorporate a wider area. The farmers and experts of this study were mainly active in the consolidated zone. Farms that are located closer to the forest frontier should be included to see whether the trends asserted in this study can be confirmed. In effect, especially the effect of distance to the forest frontier on a farm’s tendency to establish SPS and on intensification could be better evaluated. This would generate further evidence on the Boserup hypothesis.

- In general, more data generation of processes at the forest frontier is necessary to better understand deforestation processes in Colombia and Caquetá. Interview partners claimed that farmers at the frontier are financed by so called “big enterprises” which potentially belong to the agricultural and/or the timber industry. This claim so far remains to be proven and could be supported through interviews with farmers at the forest frontier.
- Equally important is the investigation of migration processes of farmers that have to sell their land in the consolidated zone to build new farms at the forest frontier. These processes remain under-investigated. A possible indication could be the investigation of land-price changes. An increase of land-prices would also support the Boserup hypothesis.
- As a further point, the effect of supply changes of meat and milk on the price and on demand remains to be investigated to be able to better estimate the effect of SI through SPS on farmers’ livelihoods and on their tendency to expand or decrease their farm land.
- A more precise analysis of the agricultural information and knowledge system in the region could help to understand how knowledge of sustainable production technologies such as SPS reaches farmers. So far it seems that agricultural information is mostly distributed through organisations in the consolidated zones, but no knowledge exists on how and if information reaches remote zones. If positive direct effects of SI on deforestation exist, they can only be exploited if knowledge of these technologies actually reaches farmers at the forest frontier.

5 Conclusion

The aim of this study was to find evidence to the claim that SI reduces deforestation. To do this, the production technology SPS was analysed based on the two aspects sustainability and intensification. SPS was shown to be a sustainable production technology based on expert opinions. To study the intensification of SPS, the log-means of the variables annual milk yields per hectare, annual labour days per hectare, and stocking rates were compared using t-test. Hard evidence of SPS intensifying livestock production applied in real world scenarios could not be generated, since t-test results lacked significance. However, log-means of the variables of intensity indicated the expected direction. Therefore, results might turn out to become significant once systems are further established and available data is more detailed.

Nevertheless, whether SPS can be considered SI depends on the definition of SI, as it could not be demonstrated that farmers with SPS do not expand agricultural land. As a proxy for deforestation, the study used the forest reserves of individual farmers, which were defined as the farmer's amount of forests in relation to their total land. The linear regression model built for this study did not find a significant relation between forest reserves and the chosen variables of intensity: annual milk yields per hectare, annual labour days per hectare and stocking rates. Therefore, neither the claim that agricultural intensification protects forests from deforestation nor the opposite could be proven. For this reason and contrary to economic theory, these results suggest that the link between intensification and deforestation is weak, as has been shown before. Furthermore, the study found that farmers who apply SPS have significantly less forest reserves, which can be interpreted as that a focus on sustainability in agricultural intensification does not perform better in the protection of forests. An alternative explanation for the lower forest reserves of farmers with SPS was offered by suggesting that the introduction of SPS is a result of low forest reserves instead of the cause.

SPS remain to have high potential to improve a number of sustainability indicators such as farmers' livelihoods, biodiversity, GHG emissions, among others. Even though this study could not produce evidence of SPS as an innovative mechanism to increase intensification and forest protection, the continuing research over time of this still young innovation prevails to be promising for the target of SI. Nevertheless, it should not be expected that the problem of deforestation can be solved merely by SI without a strong focus on governance of natural resources. The research of deforestation by smallholder agriculture in Caquetá should be expanded from a farm-level perspective in order to include migration patterns of farmers to the forest frontier. Further research should be conducted to model the trade-offs between deforestation and other indicators of sustainability in order to be able to better evaluate the risks of a land-sharing approach in SI.

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7 Annex

7.1 Table of Interviews

Method (eg focus group, individual interview etc)	date	place/region	No. of participants	gender	type of participant	transcript no
individual interview	10.11.2019	Florencia/Caquetá	1	f	public sector, works as forensic expert trying to identify corps from violent conflict on graveyard of Florencia	191110-003607 encuesta 1
individual interview	14.11.2019	Florencia/Caquetá	1	f	workshop participant, founder of Women-NGO	191113-212810 encuesta 2
individual interview	15.11.2019	Macagual/Caquetá	1	m	farmer, student at UNIAMAZ	191114-164833 encuesta 3
individual interview	15.11.2019	Florencia/Caquetá	1	f	researcher at UNIAMAZ	191114-230142 encuesta 4
individual interview	16.11.2019	Florencia/Caquetá	1	m	CEO of local NGO	191115-144308 encuesta 6-1; 191115-144308 encuesta 6-2; 191115-144308 encuesta 6-3
individual interview	17.11.2019	el Doncello/Caquetá	1	m	Model farmer	191115-170759 encuesta 7 - 1, 191115-170759 encuesta 7 - 2, 191115-170759 encuesta 7 - 3
individual interview	17.11.2019	Montanita/Caquetá	1	m	Farmer	191115-234051 encuesta 9
group interview	18.11.2019	Florencia/Caquetá	7	f/m	Indigenous community with forest reserve in Florencia	191116-223707 encuesta cominudad uitoto 1
World-Café Panels	14.11.2019	Florencia/Caquetá	32	f/m		191113-180026 taller 2, 191113-190641 taller 3, 191113-193812 taller 4, 191113-200946 taller 5

7.2 Posters of Participatory Workshop

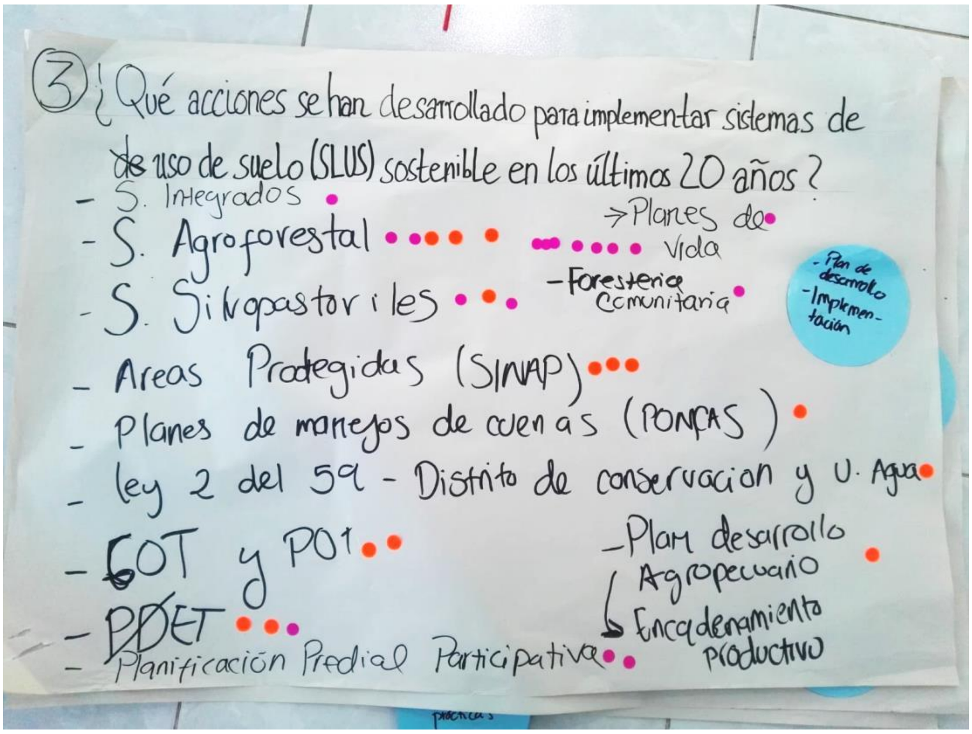

Figure 12: Poster Number 3 of Participatory Workshop

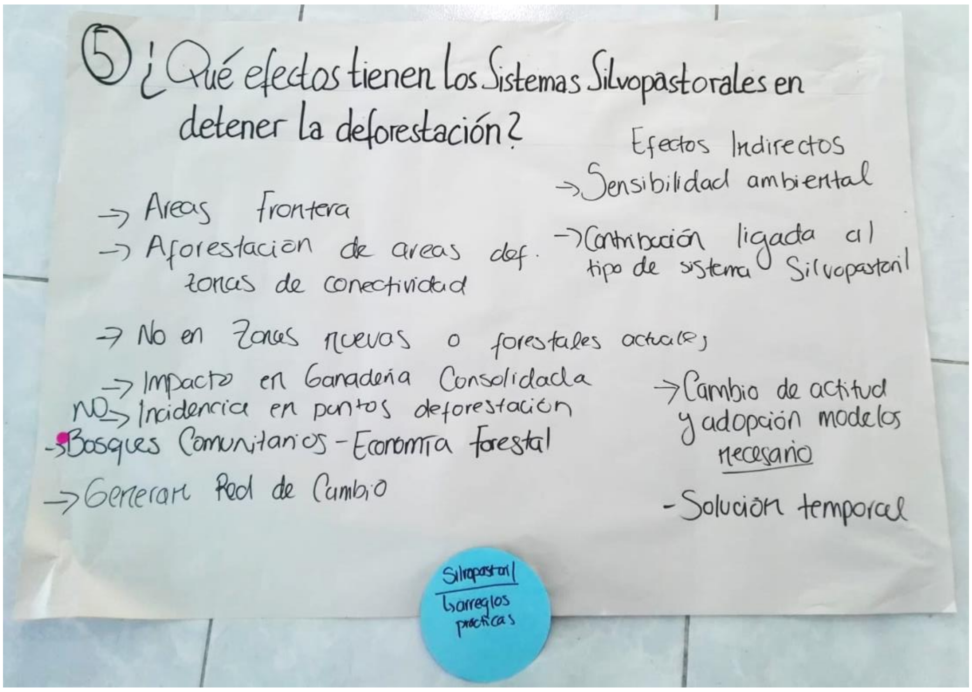

Figure 13: Poster Number 5 of Participatory Workshop

7.3 Interview Guideline

Sistemas de Uso Sostenible de la Tierra y Construcción de paz ambiental V.2.

0. Tipo de Actor

- ☐ Global thematic expert
- ☐ National (Colombia) thematic expert
- ☐ Local thematic expert
- ☐ Farmer

0.1. Field of expertise____________________________________

1. ¿En cuál municipio y corregimiento vive?

____

1.1. ¿Vive en zona urbana o rural?

- ○ Urbana
- ○ Rural

2. ¿Actualmente qué tipo de actividad económica desempeña?

- ☐ Agricultura
- ☐ Forestería
- ☐ Pesca
- ☐ Ganadería
- ☐ Servicios
- ☐ Transporte
- ☐ Comercio
- ☐ Sector Público
- ☐ Otro- Cual

2.1. ¿Cuál?____________________________________

3. Tipo de tenencia de la tierra
Elija una de las

- ☐ Propio
- ☐ Arriendo
- ☐ Aparcería
- ☐ Usufructo
- ☐ Comodato
- ☐ Ocupación de hecho
- ☐ Propiedad colectiva
- ☐ Adjudicatario o comunero
- ☐ Otra Forma
- ☐ No sabe

3.1. ¿Cuál?____________________

3.2. ¿Tiene títulos formales de la tierra?

- ○ Si
- ○ No

3.3. ¿Cuántas hectáreas posee?

____

4 ¿Desde hace cuánto tiempo habita en el municipio?

____

5. ¿Ha observado cambios en el uso de la tierra en los últimos 10 años?
Explíque

____

6. ¿Han habido programas de restitución de tierras en su municipio?

- ○ Si
- ○ No
- ○ No sabe / no responde

6.1. ¿Usted ha participado?

____

7. En una escala de 1 a 5 donde 1 es muy malo, 2 es malo 3 es regular 4 es bueno y 5 es muy bueno ¿Cómo calificaría los programas de restitución de tierra?

- ○ 1 Muy malos
- ○ 2 Malos
- ○ 3 Regulares
- ○ 4 Buenos
- ○ 5 Muy buenos

7.1. ¿Por qué dio la calificación anterior?

---

8. ¿Qué valor tiene para usted el bosque en su vida?

- ○ Muy Valioso
- ○ Valioso
- ○ Normal
- ○ No tan valioso
- ○ Nada valioso

8.1. Explique su respuesta anterior

---

9. ¿Usted se lucra del bosque?

- ○ si
- ○ no

9.1. ¿Cómo se lucra del bosque?

9.2. ¿Participa de alguno de los siguientes programas?

- ☐ Pagos por servicios ambientales
- ☐ Familias guardabosques
- ☐ Bonos de Carbono
- ☐ Forestería
- ☐ Otro

9.2.1. ¿Cual?____________________________________

10. ¿Ha experimentado degradación de la tierra en su predio?

- ○ si
- ○ No

10.1. ¿Cómo y de qué manera se ha manifestado la degradación?

---

12. ¿Usted aplica prácticas de manejo sostenible de la tierra en su predio?
Por ejemplo: Rotación, diversificación de cultivos, agroforestería, sistemas silvopastoriles

○ si

○ no

12.1. ¿Cuál práctica de uso sostenible de la tierra ha aplicado?

---

14 ¿Conoce sistemas agroforestales? ¿Cuáles?

---

13. ¿Sabe qué son sistemas silvopastoriles?

○ si

○ no

13.1. ¿Qué tipo de sistemas silvopastoriles tiene en su predio?

☐ 1. Arbustos dispersos

☐ 2. Bancos de forraje

☐ 3. Silvopastoril intensivo

☐ 4. Cercas vivas

☐ 5. Árboles en Franja

☐ 6. Otro

13.1.1. ¿Cuál?______________________________

15. ¿Cuáles son las principales dificultades en las actividades de producción agropecuaria?

---

16. ¿Percibe que el cambio climático ha afectado su producción?

○ Si

○ No

16.1. ¿Cómo ha afectado el cambio climático su producción?

---

17. ¿Cuántas personas trabajan en la finca?

---

18 ¿Que rol desempeñan las mujeres en la finca?

---

19. ¿A quién o dónde vende usted sus productos?

---

20. ¿Cuáles son los principales obstáculos para vender sus productos?

21. ¿Cuáles son las actividades económicas más rentables en su municipio?

22. ¿Existe un espacio social donde su comunidad discutan problemas compartidos que los afectan y sus posibles soluciones?

Decisiones públicas hacen referencia a asuntos que no son del nivel privado o familiar pero que afectan a toda la comunidad. Por ejemplo la construcción de una carretera o acueducto

- ○ si
- ○ no

22.1. Describa ¿Sobre qué discuten? ¿Qué tan frecuente se reúnen? ¿Quiénes participan?

25. ¿Manejan colectivamente el uso de los recursos naturales?

- ○ Si
- ○ No

26. ¿Cómo se maneja el acceso a los recursos naturales en su comunidad?

27. ¿Cómo ha cambiado el manejo de los recursos naturales en los últimos 5 años?

28. ¿Usted participa activamente en los escenarios de decisión de política pública?

- ○ si
- ○ no

28.1. ¿De qué manera participa en la decisión de política pública?

Por ejemplo: Representante de la comunidad, elecciones, haciendo cabildeo con políticos, a través de mi asociación de campesinos, etc.

29. ¿Qué significa la paz para usted?

30. En una escala de 0 a 10 donde 0 es nulo y 10 es muy alto ¿Cuál es su percepción del nivel de paz en Colombia?

0 10

31. En una escala de 0 a 10 donde 0 es nulo y 10 es muy alto ¿Cuál es su percepción del nivel de paz en su municipio?

0 10

40. ¿Cuál considera es el área prioritaria que se debe promover para consolidar la paz en su región?

- ☐ Herramientas para resolver los conflictos de manera pacífica
- ☐ La posibilidad de participar políticamente en escenarios de decisión pública
- ☐ Generación de ingresos económicos
- ☐ Justicia Transicional (Reparación, Verdad y no repetición)
- ☐ Seguridad Policial
- ☐ Otro

40.1. ¿Cuál?

32. ¿Qué significa el conflicto para usted?

34. ¿Qué tipo de conflictos considera que existen en su región?
Si el conflicto es acerca de recursos naturales explique cuál.

35. ¿Considera que el acceso a la tierra es un factor causante de conflicto en su región?

- ○ si
- ○ no
- ○ No sabe

35.1. Explique que rol ha jugado el acceso a la tierra en el conflicto

36. ¿Se siente amenazado por algún conflicto existente en su vida diaria?

- ○ si
- ○ no
- ○ No sabe

36.1. Explique cuál es el tipo de conflicto y amenaza que experimenta en su vida diaria

37. ¿Ha sido usted afectado directamente por el conflicto armado?

- ○ si
- ○ no

37.1. ¿Está usted registrado en el Registro Único de Víctimas (RUV)?

- ○ si
- ○ no

39. En dado caso de que el conflicto sea por acceso o uso de un recurso natural. ¿Cómo resuelven el conflicto?

41. ¿En quién confía para resolver conflictos en su comunidad?
Autoridades gubernamentales, mediador, juntas de acción comunal

42. ¿Ha recibido entrenamiento en manejo o trámite de conflictos a través del diálogo?

- ○ si
- ○ no

42.1. ¿Cuál?

43. Si tuviera la oportunidad de recibir capacitaciones sobre resolución de conflictos o mediación. ¿Asistiría?

- ○ si
- ○ no
- ○ No sabe

44. Género

- ○ femenino
- ○ masculino
- ○ Indefinido
- ○ Prefiere no decir

45. Edad

46. ¿Cómo describiría su etnia?

- ○ Mestizo
- ○ Afrocolombiano
- ○ Indígena
- ○ Blanco caucásico
- ○ Gitano
- ○ Otro

46.1. ¿Cuál?______________________________

47. ¿Cuál es el ingreso mensual aproximado de su hogar?
En Salarios Mínimos Legales Vigentes (SMLV) 800 mil pesos aprox.

- ○ < 1 SMLV
- ○ 1 SMLV
- ○ >1 hasta 10 SMLV
- ○ > 10 SMLV

48. ¿Cómo la cultura/identidad local influye en el manejo de los recursos naturales?

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7.4 Content Analysis of Interviews and Workshop

Quote	Code
Encuesta 3:	
Si entonces tu haces uno rotario, rotario, rotario y pues vuelva otra vez y entonces diría que para hacer un manejo sostenible del suelo tendría que ser bueno tener una incorporacion de mucha no solo hierba, bueno manejar un estrato herbolio durante... ejemplo yo tengo pastura, tengo arbustos y tengo arboles, eso sería el ideal, sí, pero implementar eso lleva tiempo y es muy costoso porqué tu como tal tienes já un (unv.) de ganado y adequar un hectaría te gostaría dejar quieto eso uno o dos anos quietos para formar uno estrato arbolio/herbolio(?). Entonces el fincario no tiene toda esa area para dejar una area quieta, inproductivamente para... #00:18:37-1#	Weakness of SPS
I: Y cuales de las practicas para frenar la degracacion recomendacías a otros ganaderos? #00:19:11-0# B: Rotacion! Delimitacion de potreros y rotacion. Es la mas practica y dejar especies que son netas del dapartamento que pueden ser potentialo en sistema silvopastoriles, por lo menos acutalmente los que creces muy facil son Guayabos y Limones, el Mandarino que le hicen actualmente acá y otros que le hicen Arrayan, hay varidades de aceitunas, hay unos arbolitos que comportan muy bien y que uno va dejando en los potreros y se van adaptando bien. #00:19:52-0#	Opportunities of SPS
Sino que se vayan dejando en raleo (?) las que van haciendo, porqué como tal implementar un sistema silvopastoril saldría muy costoso. O mantener un sistema silvopastoril, yo creo no es tanto el establicimento sino el mantenimiento. Si en primera estancia lo que es la mas limitante porque usted como tal leamos estos, leamos las cercas, leamos lo instatillo, leamos lo plantulas, leamos todo. Y se siembre... Pero de allí el mantenimento es lo mas duro, porqué el agriculutor empezando lo duro mantener su unidad productiva y mantener lo otra que cuesta (unv.) el mantenimiento de las cercas. Entonces todo eso le genera muy desperdioso a eso porqué especialmente los campesinos o los productores del departamento ahorita hoy en día la escasa de mano de hora es muy limitada, entonces de mandar les otra carga que tiene que	Weakness of SPS, Threats for SPS, Strength of SPS

hacer sería muy costoso. Entonces por eso se caen los sistemas silvopastoriles. Ellos entienden la importancia (unv.) quizas no todos, pero hay algunos que si entienden el papel del arbol y cuanto hay sombrillo para el ganado, que mejora el tema de la biodiversidad, que mejorar la sostenibilidad del suelo. ...ver como un proceso (unv.) los arboles que crescan allí, hay que implementar arboles que a vezes se ha cometido errores porqué son especiez intrucidas y no son como un especiez que cumple un circlo importante en el departamento. (unv.) Diría yo que sirve mas como para aprovechamiento forestal a los 15, 20 anos, pero no cumple a la alimentacion de avez, o circlo vital. Y usted le quita el espacio, debe ser ese arbol, puede ser otro arbol que si cumple un circlo importante en las especies del departamento. #00:22:34-9#	
I: Que tipos de sistemas silvopastoriles tiene en su predio? #00:22:44-6# B: Arbustos dispersos. Bancos de forraje, Sistmas de Silvopastoril intensivo es muy costoso. Cercas vivas, si algunas partes se trata de hacer. Arboles en franja, la tuvimos pero, se caen porqué demando mucho, y el tema ahorita hay un problema de hormigaiera y eso como estan arboles introducidos, se le comen todo. Arboles dispersos y bancos de forrajes son los que mas hay. #00:23:23-0#	Weaknesses of SPS, Threats for SPS
I: Y está adabtando con especies local! #00:23:23-0# B: Si, porqué es mejor. Digamos que usted va a tumbar un canedo(?) o en un proceso (unv.) succesion ecologico, puedes tumbar todo y puedes quemar, sí pero ahí retonan, entonces uno va dejando disperso los arboles importantes, y van siendo un arboles dispersos, un sistema silvopastoril de arboles dispersos. Para gente que humiga todo y solo deja pastura, entonces una va haciendo (unv.) unos arboles arboles muy bueno, (unv.) otro, otro, otro... já. Y despues cuando já esten grandes, comienza un tema de poda, que entra la luz y cuando já hay muchos arboles, pues hago un raleo (?) y já mantengo/hago un silvopastoril que no me ha costado tanto, que yo tengo que hacer un semiliero para o algo (unv.) que por lo menos te dona las plantas. Las fincas aquí el tema de que donde hacer el sistema silvopastoril a la caretera principal (unv.) Despuene que entran a la finca y despues de que entran al lote. Tu siembras y occure un dia de alto sol y se destruican todos las plantas,	Opportunities of SPS, Threats for SPS

entonces se pierda todo ese trabajo. Si porqué uno (unv.) (estremer) en bolsas pequenas, já está pasar el raiz, el trabajador no lo siembra con amor, entonces se pierde todo el trabajo, es un costo economico que se hizo en eso que eso es la verdad es perdido. Entonces todos los recursos invertido en eso se queda en la assistencia tecnica en los que diregen los proyectos y el productor solo le cadan unas plantas que no sé sembrar bien, un proceso en campo que no se hizo bien. Entonces siembre se causa, por este es mejor as vezes las sistemas silvopastoriles que han un incurrio majores sito en la finca son estes. #00:25:16-6#	
Entonces el renglon productivo numero uno practicamente del departamento. Aunque pues ahorita já han venido possesionando otros renglones productivos como el cacao, el caucho, si, pero pues muy bajo, si me hago entendere, el fincario que tiene ganadería tiene su pedacito de cacao tal o pedaco de caucho pero el renglon principal siempre viene siendo la ganadería. Como tal el otro cultivo no es su renglon principal es un renglon alterno que tiene pero siempre si viene la ganadería como el primer renglon. Pues ese fue en su principio que creció el Caqueteno y el que sabe manejar mas mejor. #00:04:56-0#	Livestock
I: Cuales son los actividades economicas mas rentables en su municipio? #00:32:03-2# B: La ganadería es la unica. Rentable no, pero es la actividade de subsistencia del departamento. Pues hay gente que si la hace sustentable pero aquí quien tiene lo major recurso puede invertir mas. tiene mas extension de tierra, major inversion y pues obviamente puede hacer no solo lechería si no el tema de engordo. Pero como tal el renglon que hace un sostenimiento en el departamento es la ganadería. #00:32:31-6#	Livestock
I: Cuales son los principales obstaculos para vender sus productos. #00:31:24-6# B: El tema de la leche ahorita está bien. El tema es que se ha afectado as vezes por el tema de los precios. Bajan los precios pero como tal si se han caratizado la compra de la leche. O el tema de que se ha mucho afectado la economia ahorita lo productores el tema este cuando se cierran vías o cuando ahorita los procesos de paro, ahí es cuando la	Livestock

gente sufren mucho. Porqué se para todo, ejemplo el ciclo productivo, entonces já no hay quincena. Sí, entonces ahí la gente comienzan a sufrir. #00:31:57-6#

I: Y como, cuando tiene que abrir un poco las areas de bosque, que hace? Que practicas aplican? #00:10:00-3#

Deforestation

B: Vea como tal en la finca ahorita hoy como dos areas, hay una area de que ocurió un proceso de se dejado en rastrojado la finca, y aquí (unv.) un proceso de succesion ecologica en rastrojo, si me van a entender? A vezes si se tumba para hacer nuevos potreros de pasturos, si? Pero como tal el bosque si se preserva, las areas de bosque, son dos bosques y eso se preserva, no se toca. No, para implementacion de algun cultivo o de pasto no, nada. #00:10:35-6#

I: y cuando, digamos las fincas que la hacen, como lo hacen? #00:10:41-0#

B: Pues, tumba y quema. #00:10:43-0#

I: Solo quema todo? #00:10:43-8#

B: si, claro. #00:10:45-9#

I: Y luego, que pasa despues de esa quema? Dejan esta zona? Cuanto tiempo para emezar a regenerar? #00:10:53-3#

B: No, pues donde está creciendo la frontiera agricola actualmente en el departamento es tumba y quema si me aguante entender? Y pues es por ejemplo un baldío el que agarré (?) 100, 200, 300 hectarias. Pues cada ano tumba la medida en que puede, todo es por decir este ano este programa tumba cinquenta, pues eso se quemó. Hecho algun cultivo de pan coger (unv.) #00:11:22-5#

I: Y cuanto tiempo se demorar la quema y luego (unv.)? #00:11:28-3#

B: (unv.) solo pasto #00:11:32-6#

I: Pero esta instantánea o te revieres a unas, dos semanas? Eso se pasa rapido? #00:11:38-3#

B: Las tumbas en el departamento del Caquetá sean principalmente en los meses de diciembre e enero, en las epocas secas. Para que en febrero esté quemando y cuando entré en marco las lluvias, pues já usted puede regar el pasto. El pasto germina en dos meses (unv.) una pastura. En julio lo que era antes bosque já es pastura. #00:12:03-9#

I: En unos meses? #00:12:04-7#	
B: Si, en unos meses. Digamos entre diciembre y junio este que já lo que era bosque (unv.) convertió en pastura. Nada mas. Y por él que evita de una vez por los menos si crees por lo menos un rastrojo no ha sido bosque, pues quema, hecha pastura y lo que nasca rastrojo y una le hecha glifosato para el tema de control de malezas y queda solo pastura. #00:12:27-0#	
I: Piensas que la tumba y quema está financiado de empresas de fuera del Caquetá? #00:13:14-7#	
B: Como digo yo, por lo menos yo, siendo hijo... por lo menos yo hablo por los familiares que tengo en Cartagena, San Vincente por lo menos, el nuncleo de familias está mamá y papá y ellos tienen su finca, (unv.) quiere (unv.) tierra pues se va tumbar, si me van ha entender. O hay gente que solo se dedica, o gente que tiene recursos economicos pues va y arreglar fincas. Y el que tiene mas recursos economicos le compra esa mejorar y já pasa así. Pero como tal ahorita en el departamento creo que acaparamiento por empresas o algo así no sé. #00:13:55-2#	
I: Cuales son los principales dificuldades en las actividades de producion agropecuaria? #00:26:20-4#	Threads for SPS
B: la mano de obra falta. si porque está viendo que por lo menos uno los hijos nos venímos a estudiar. #00:26:29-9#	
I: El problema es que no gente o que no hay denero para pagar la gente? #00:26:45-4#	
B: los dos! El sistema productivo no es tan altamente eficiente para contractar mano de obra para trabajar en la finca. O as vezes que se escarese la disponibildad de mano de obra cualificada. Porqué hay gente que tu la contratas pero pues es como muy capacitada para eso. Va hacer un trabajo mal hecho entonces todo se caiga. #00:27:21-0#	
Encuesta 4:	
I: Me interaría investigar que sistemas silvopastoriles serán mejor para los pequenos productores y que sirven para mas grandes? #00:50:52-7#	Strength of SPS,
B: Si, si quiere yo los comparte los documentes porqué... Lo que se busca es, existen diferentes modeles, hay aproximamente los 12	Opportunities of SPS

modelos, de los cuales 9 le sirven al Caquetá por el clima. Entonces que tiene relacion con cercas vivas, cercas rompevientos e con todo lo que se hace para guardar alimientos para. #00:51:30-5#

I: Pero tambien algunos son mejor para autoconsumo me imagíno, otras mas con frutas que se puede vender en el marcado o no aplica? #00:51:40-8#

B: Si, aquí aplica que la majoría de ganaderos quería que sean maderables. Digamos que ellos hacen mucho ènfasis en los arboles maderables para vender, para utilsar esa madera. Porqué como puede observar por la majoría de los fincas en los municípios las casas son de madera. Toda la infrastructura es de madera. #00:52:20-9#

I: Pero sistemas que enfoquen a la seguridad alimentaria no hay? #00:52:32-6#

B: La majoría de especies que usan son los maderables, y algunos frutales. Pero si sería muy interesante concocer un sistema, o por lo menos implementar un sistema o un piloto para que tenga enlace con la seguridad alimentaria. Pues que productos sean? Serían frutales, e si se emplementan frutales pero sobre todo los maderables. Digamos por la comunidad es muy atractivo cuando se le implementan especies maderables.

I: Han observado cambios en el uso de la tierra en los ultimos anos? #00:00:24-9#	Livestock Deforestation
B: Si, realmente unos de los problemas fundamentales en el Caquetá a sido precisamente eso. Una de las variables es la ganadería extensiva. Porqué es una manera de explotar la tierra de forma inadequada, porqué normalmente el ganadero de Caquetá lo que hace es tumbar grandes extensiones de bosque para generar potreros (unv.) tiene su vacas, su ganado y ese ganado no es totalmente productivo. Existen tambien otras variables que es la falta de nutrientes entonces cuando se tumba el bosque se amplia la frontera y el constante pisoteo del ganado hace que la tierra se vaya errosionado, produsca errosion, salgan malesas. Toda esa cuestíon hace que la tierra no sea tan productiva como se espera. Otra de la caracteristicas que tiene la ganadera en Caquetá sea la carga. La capacita de carga en el Caquetà es de 1.7. Es de decir 1.7 unidades	

de ganado estan en un hectaria. Pero eso es al nivel general del Caquetà pero al nivel municipal he tenido la experiencia de trabajar con... al municipio de Solita donde la capacita de carga es de una vaca por hectaria. Otro de los municipios que salen aun peor es Curillo que presenta 0.5 cabezas por hectaria. Cuando normalmente en un sistema sostenible se puede tener 10 unidades de vacas por hectaria. Entonces eso es una de los problemas relacionandos a este sistema. #00:02:44-6#	
I: Pero ha cambiado en los ultimos 10 anos mas que antes? #00:02:45-8# B: Si, es una de los caracteristicas por los cuales ha sucedido eso es la retirada de la guerilla porqué ellos permitieron al retirar se de los valdidos de la sierra que tenian bosque lo que paso es que los ganaderos o las personas se expandieron, abrieron frontieras y pues que suelon hacer en el Caquetà es tumbar bosque y definir potreros. Para ellos aca una finca cuesta por los potreros que tenga no por el bosque es decir el bosque en este momento no es valioso para ellos es valioso decir (unv.) esa finca que tiene cien hectarias de potreros. Entonces eso es valioso para ellos, una finca cuesta mucho dinero. Pues eso es una de los concepciones digamos que es la cultura del Caqueteno. #00:03:45-9# I: Pues dice que la ganaderia hay grande parte en la deforestestacion en el Caquetà? #00:03:52-9# B: Si, unos de los estudios que realicaron dice que el Caquetà es el foco de deforestación en Colombia. Cartagena del Chaira es el mayor deforestado y hay algo muy grave que es Solita es uno de los municipios que cuenta con mayor bosque en el departamento y fue uno que se rasó en los ultimos tres anos cuando se retrió la guerilla empezaron a envadir esos terenos y actualmente se esta tumbando. Otro de los factores relaciondo con la deforestacion tambien es que no son los comunidades que estan tumbando. Porqué la comunidad no cuenta la herramienta para tumbar. Son empresas muy grandes que cuentan con los recursos, que invierten dinero, en maquinaria, en transporte para sacar esa madera... Porqué el negocio esta en la venta de madera. Y otro de los negocios que se va a ir con relacion a la ganadera son grandes ganaderos. No son los pequenos porqué los pequenos cuentan máximo	Deforestation Livestock

10, 15 rezes. En cambio un ganadero... #00:05:18-5# I: Pero son los grandes que invierten para que los pequenos pueden deforestar o son los grandes que van aya para deforestar. Cual es la logica? #00:05:25-6# B: No, el problema que existe actualmente es que dicen los campesinos que ellos no tienen la capacita de tumbar o sea, el problema no son los pequenos campesinos, el problema son los grandes, las emprezas grandes que venden madera. Las emprezas grandes lo que hacen es invertir en maquinaria para hacer tala de muchisimas hectarias de bosque. Ellos talan 200, 100 hectarias de bosque en un, dos meses. Porqué ellos cuentan con la herramienta para hacerlo. Un campesino no tiene la herramienta puede tener una sierra y cortar unos tres arboles al dia. Una empreza con maquinaria puede tumbar muchismo. Entonces eso es uno de los conflictos. #00:06:14-6# I: Dicen que tambien son los grandes ganaderos que apoyan a la tala. Como se puede diferenciar cual es el limite. Que es un grande ganadero, que es un pequeno ganadero, que es un campesino? #00:06:31-7# B: Actualmente existen estudios sobre el que es un grande y que es un pequeno. Yo le comparto unos documentos. (unv.) ...que han realisado distictos estudios y pero se los identivica muy facil porque un pequeno ganadero no supera las 30 hectarias. Digamos que unos tienen 50. Pero un grande ganadero solo (unv.) porqué tiene muchissmas hectarias, 200, 300 hectarias. Y tiene 100, 200 rezes. Porqué se supone que la capacita de carga es una por hectaria. Y un pequeno ganadero siempre tiene máximo 10, 15 rezes. Entonces eso es la diferencia. [...] El grande já supera eso. (unv.) pero igual el ganadero pues que dedican, o pues la ganadería en el Caquetà es como un eje fundamental porqué hace parte de la economía. #00:08:00-7#	
I: En este conjudo de que hablemos sobre las programas de restitucion me interesaría: piensa que los sistemas silvopastoriles son una manera de detener la deforestación? #00:15:50-5# B: Si, dentro de (unv.) que tengo en la formulacion de los documentos porqué la parte de fomular los a ido a los comunidades y si realmente	Opportunities of SPS Strength of SPS

esto es una solucion a cortoplazo para detener la deforestacion en el Caquetá porque el Cauqeta es un 50% ganadero. #00:16:13-5#

I: Porqué ayer tambien preguntamos la pregunta y mucha gente dicen no, no es para deforestar pero hace un bosque segundario pero en realidad no protege al bosque primario. Pero lo que pienso o el profesor [nombre] dije que cadena de logica es que los ganaderos de aqui no pueden mas trabajar la tierra porqué es degradada pues tienen que vender su predio y despues van a la selva para tumbar y si aplican silvo pastoriles no tiene que vender porqué es productiva, pueden vivir de su tierra y no tienen que ir a la selva. Que piensa de esta logica? #00:17:15-6#

B: Pues la primera parte que el bosque secundaria no es importante o sea... digamos que si se implementa los sistemas silvopastoriles si se detiene la deforestacíon porqué ellos van a cambiar la concepcion de tumbar el bosque para ingresar mas vacas porqué es que aqúí el piensamento es que si yo voy a comprar una vaca mas nececito tumbar un hectaria para esa vaca. Entonces con los sistemas silvopastoriles se va sobrar espacio. Porqué en un sistema silvopastoril de un hectaria se puede sacar cuatros potreros aquí lo minimo - los estudios que se han realizandos - es que - son cincos hectarias con sistemas silvopastoriles para que sea eficientes. Solo cincos, es lo basico. En cinco hectarias usted puede hacer la divicion de potreros, cuatros por hectaria en la cual puede hacer la rotacion. Usted ingresa diez rezes en un potrero y va haciendo la rotacion cada dos dias. 2,5 dias usted hace la rotacion. Cuando usted llega al ultimo potrero ya el primero se ha empezado a restaurar entonces usted lo que hace es volver empezar el ciglo y vuelve y ese es el sistema. Las mimima son cinco. Entonces si una person aquí tiene muchos hectarias (unv.) tener espacio para poder hacer su rotacion tiene que hacer una inversion, claro, y si lo puede hacer. Si es una forma de frenar lo porqué cambiar esa cultura de tumbar para ingresar mas animales por un lado. Y por el otro lado si el bosque segundario no es tan importante como el primario pero si se llega a reforestar pues sería maravilloso, no? #00:19:08-9#

Encuesta 6-2

I: Cuales son los principales dificultades en la producion agropecuaria aquí? #00:30:49-1# B: Son muchas! Uno de las problemas que yo veo y que es gravísimo acá que uno ve. Primo la vision! La gente no mira la finca como una empresa, la gente mira la finca para algo mas para producir mientras las personas no miren que finca es una empreza. Va ser muy dificil que salgan adelante. Porqué si tu no miras la finca como una empresa tu no vas a generar ingresos economicos. No son emprezarios. Son gente que le falta mucho conocimiento emprezarial. Eso es un tema. El segundo tema que yo veo es la cualificacion. la generacion de capacidades. la gente tiene legado conocimientos tradicionales y no tiene conocimientos actuales, technologías actuales, tecnicas, aprendizajes. conocimientos que pueden servir. Pero ellos no lo toman porqué muchas vezes es que mi abuelo lo hacía así, mi padre lo hacía así. #00:32:06-8#	Livestock
I: Y que pensas, los silvopastoriles son una solucion por todo los problemas de la gandería en Caqueta, la degradacion, deforestacion. #00:03:32-8# B: Yo pienso que sí son una solucion. Es una alternativa para el departamento para el departamento. Porqué aparte del confort del ganado, la sombra. El ganado cuando está en mejor confort con mas sombra, reduce la temperatura. El ganado se comporta mejor. El rendimiento productivo es major cuando el bienestar del animal. Y por el otro lado tambien se metiga mucho que el sol pege tan fuerte directamente en la tierra. Tiene en cuenta ese tipo de cosas e consectos. Creo que de una o otra manera termina beneficiando la ecología del sistema. Por otro lado terminar beneficiando la economía del productor. Y creo que las personas que implementan los sistemas silvopastoriles tienen major sensibilidad ambiental. A tener major sensibildad ambiental porqué? Porqué yo dice 'mi tierra antes esto era puro sol, mucha temperatura. Ahorita está mejor, mi tierra mejorado. Hay que cuidar el medioambiente.' Y ellos empezan hacer divicion de potreros. comienzan a pensar bueno como puedo producir mas. Já solucionen el problema de la temperatura. Ahora como puedo producir más? [..]Comienzan hacer otras serie de cosas que vanle al sistema	Opportunities of SPS

silvopastoril. #00:05:11-0#	
B: Lo que pasa es que la zona de consolidacion si existe. Es una zona donde la ganadería já es vieja. Y en está zona já la tierra está mas degradada. Y en algunos casos está tierra já pasa procesos de desertificacion. Los niveles de lluvia disminuyen y los pastos, si no hay agua son poco productivos. [...] Por eso esa gente lo que pasa es que buscan nueva finca. Nueva finca o nuevos teritorios para colonizar y tener eso. Tener mas tierra. Sin embargo yo pienso uno de los problemas en Solano Caquetá y San Vincente de Caguan es que los que están teniendo negocio de la ganadería son gente que viven en Bogotá, en Cali y en Medellín y son grandes emprezarios que tienen bastante denero para hacer inversiones de 2000 hectarias, 3000 hectarias. Entonces ellos son los que envían gente de Medellin, contratan una gente de acá. Compran las tierras, (unv.) terratenientes. Y ellos son los que realmente estan generando el problema. #00:01:42-0# I: Pero como profitan esta gente de Medellin? #00:02:00-5# B: Primero inician los pequenos, son los que comienzan deforestando, colonizan. #00:02:06-5# I: Pagados por los de medellin? #00:02:09-3# B: No sé si sean pagados. Pero si he visto mucho que comienzan los pequenos, montan una pequena finca. Colonizan un res (?) de tierra virgin, es tierra baldía, viene un grande, y el pequeno se revende estás hectarias, el grande compra y ese si comienza a deforestar esa tierra virgin. El grande. De lo todo es systemico. Es en cuanto a ellos. En cuanto a los sistemas silvopastoriles la implementacion lo que (unv.) se dió parte todo por qué algunos proyectos institutionales y otros que son de coperacion comenzaron a trabajar sobre la implementacion de sistemas que combinen los pastos y los arboles. Para pensar un poco en el cambio climatico, mitigar los gases de efecto invernadero. Todo este tipo de cosas. Y montan esos sistemas para pensar en algo como confort de ganado. #00:03:17-5#	Deforestation Strength of SPS
B: Lo que pasa es que San José de Fragua era muy productor de cana. Y el otro tema es que el problema de la ganadería o lo que ocure es que la cana no ha flujo de caja! Mientras que la ganadería, la leche usted	livestock

recibe un cheque quincenal, y este cheque le mermite al campesio y al productor comprar la remesa, no sé que. Los otros cultivos son a varios meses, dos meses, tres meses. Entonces el productor no tiene un flujo de caja para poder esto mantener, las actividades de la finca y para comprar sus remesas. Eso es lo que ha permitido que la ganadería se mantenga en el tiempo en el Caquetá. Aparte de eso cuando usted tiene el terrnero, el ternero en la cría le queda libre. Tiene la leche y cuado cresca el ternero, lo pueda vender. Y entonces la gente tiene ganancia tambien del ternero. Por eso la actividad economica, la ganadería ha sido la que ha liegado este departamento. #00:23:18-2#	
I: Desde cuantos anos estan implementando silvopastoriles aquí en la zona? #00:13:41-5#	Threats for SPS
B: Se comenza a muy baja escala hace 20 anos. No obstante los ultimos diez anos já fue un poco más (unv.) #00:13:55-4#	
I: Que es su opinion? ahora los sistemas son buenas? Funcionan todos? O tenemos mucha investigacion mas? #00:14:02-6#	
B: Yo pienso que toque hacer mas investigacion porque los sistemas silvopastoriles que se han implementado hasta el momento han sido con especies foranea de la amazonia. Melina, Leucadena, Llopo, una seria de especies que no son nativas de la amazonia. Y eso genera un problema porqué la gente já piensa ha implemento já sistemas silvopastoriles con cacao, y con platano' pero el platano no es el de acá, y el cacao tampoco es de acá. Entonces genera, pues dicen que es por generacion de ingresos... Pero esas especies no son nativas del sitio y por tanto en algun momento trayen consequencias sobre el suelo y se vuelve insostenible. Lo que posibilemente vendemos como un idea muy sostenible al futuro nos vamos a dar la cuenta que no fue sostenible porqué el suelo se la acabó la matéria organica. Y de pronto el cacao chupó todo el potasio, el nitrofeo y el fosforo al mismo tiempo. Y que el cacao no hace symbiosis con el risofion (?) y no hace symbiosis con ciertas bacterias de la amazonia. [...] #00:17:37-9#	
Encuesta 7-2:	
I: en el total en el municipio hay cambio del uso de tierra en los ultimos	Livestock

10 anos? #00:04:56-0# B: Si! Mas que todo. Hace alrededor de 3, 4 anos! Que já la genete empezo a cambiar tambien! #00:05:06-9# I: Y como es el cambio? #00:05:07-7# B: El cambio es que já la gente están entendiendo que no debemos de tumbar mas montas y no aprovecharlo que tenemos, ser mas productivos, ser mas eficiente. Eso es lo que já la gente estan entendiendo. Que por decir algo aquí una persona era feliz diciendo que tenía 300, 400 rezes. Ordenar 100 vacas y sacar 100 litros de leche! Já se dió cuenta que es mejor tener 20 vacas y sacar lo 100 litros de leche que tener esas 100. Menos va contaminar, menos va acabar con el suelo. Y va ser mas rentable! #00:05:47-2#	
I: Pueden decir quien son ellos que deforestan? #00:05:37-9# B: Colonos! #00:05:43-9# I: Vienen de otros partes? #00:05:43-9# B: No! Es cultura del departamento, porqué el departamento fue colonisado! Entonces por decir algo yo, mi papá entró y tumbó montana, y eso me ensenió a mi! Tumbé montana, y yo le ensenaría a mis hijos! (unv.) Una familia tiene sus hijos y a no mas se va ser todo lo aparte. De una vez el papá o la familia o al mismo... (unv.) yo me va a ir a comprar una tierra a ser finca. Entonces arranca donde la tierra es barata, que es la montana. Y eso así es. #00:06:17-9#	Deforestation
I: Hablando de acceso. [...] Recursos naturales son el bosque, el agua, el suelo. Desde los ultimos 5 anos, fue el contrato de paz... hay cambiado el manejo de los recursos naturales aquí? #00:04:34-0# B: Si! Cuando estaba en el abuhejo (??) de los alzaba en armas. Ellos cuidaban y protegian esa parte. Cierto? Y el cambesino le tiene pavor, le tiene miedo a esta gente. entonces ellos decían: No hay que tumbar montana. nadie tumbaba un palo! Hay que cuidar esa agua! Listo! Los que culitvaban coca: No hay que tirar estes residos de la coca al agua! Listo! Hacían posos septicos, hacían todo eso. Ahora que já ellos han soltaba algo los mando en las regiones entonces está volviendo a vez la tala, se está volviendo a ver el desorden en esa parte. #00:05:29-6#	Deforestation

Encuesta 7-3:	
I: Senor, cuales son los actividades mas economicas en su municipio? #00:00:15-7# B: La base de la economia en departamento es la ganadería. Y já ahora se están dado unos cambios y esta empezando entrar lo que son los cultivos el café, el cacao. Y la piscicultura. Yo soy el representante legal del comité piscicultura del municipio y este ano con una alianza atraves del ministerio de agricultura producimos 130 toneladas de Cacan (? Kind of fish). Y 40 toneladas de Piralucu (Kind of Fish). #00:00:49-5#	Livestock
Taller 2:	
I: Que efecto tienen los silvopastoriles en detener la deforestacion? #00:36:22-3# B: (...) Las sistemas silvopastoriles los estoy haciendo generalmente a partir de ganaderías consolidarias. Cuando yo tengo un ganadero de muchos anos que já tiene practicamente todo su predio deforestado. (...) El no sigue deforestar zonas de bosque en otras territorios. (...) #00:38:02-3# C: (...) La gente que implementan silvopastoriles tienen mas sensibilidad ambiental. La familia va valorar lo que es un arbol y já no va a tumbar más bosque para formar potreros. Ademas las sistemas silvopastporiles en muchos casos vienen con division de potreros (...) Por si solo los sistemas silvopastoriles no es nada, pero genera capacidades en talleres etc. Tiene efectos directos y indirectos. #00:39:35-3# D: Los sistemas silvopastoriles tienen efecto al calientamiento global y la nutricion animal, muy diferente a la deforestacion. La deforestacion se da por amblitud de espacio que no tiene nada que ver con el sistema. (...) #00:40:17-7# E: Las sistemas silvopastoriles no contribuyen a detener la deforestacion sino que contribuyen que no se amplio, que no se deforesten nuevas zonas. Pero realmente las zonas que já estan deforestadas, no	Opportunities of SPS, Deforestation

contribuyen a esto porque já el dano está. (...) El respeto a la normatividad ambiental sería más importante para detener la deforestacion. #00:41:47-7#

I: (unv.) ... Que no servía para no deforestar las zona que hay acutalmente forestales, pero si servía para reforestar las zonas que han sido deforestados, las fincas ganaderas que acutalmente estan por completo deforestadas para forestar (...) #00:42:18-0#

E: Depende al Sistemas silvopastorils porqué hay sistemas que realmente no contribuyen tanto a la reforestacion. Por ejemplo sistemas silvopastoriles de sucesion vegetal son sistemas que pueden contribuir a la reforestacion. Pero hay sistemas que no hacen gran incidencia en la reforestación. #00:42:48-4#

D: (...) #00:47:22-5#

F: Quiero contribuir que claro contribuyen a detener la deforestación porqué es más pequena la area y se tiene más ganado. Entonces no van necesitar de deforestar otro espacio más grande, porqué já tenemos más ganado y nos alcanzen, ese espacio se va reduciendo y aumenta en carne y leche. Y no va aumentar en ganado. (...) Claro que es una manera en detener la deforestacion. Porque es que un campesino para cinco rezes necesita tantas hectárias mentras que já a cinco rezes se tiene una hectária sobrada. Entonces eso es una... para tener la deforetacion. #00:48:13-4#

E: (...) Los sistemas silvopastoriles son de corto plazo porqué seguramente en 20 anos el campesino va a cortar las arboles cuando puede vender los. (...) #00:49:16-7#

7.5 Summary of Dataset

```
library(tidyverse)
load("Dataframes/si.df.rda")
```

7.5.1 Number of Farmers with Livestock Production on Landscape "hills"

```
nrow(si.df)

## [1] 83
```

7.5.2 Number of Farmers without and with SPS

```
NoSPS <- filter(si.df, SPS==FALSE)
nrow(NoSPS) #Number of farmers without SPS

## [1] 68

SPS <- filter(si.df, SPS==TRUE)
nrow(SPS) #Number of farmers with SPS

## [1] 15

nrow(SPS)/nrow(si.df) #percentage of farmers with SPS

## [1] 0.1807229
```

7.5.3 Summary of Key-Variables of Total Dataset

```
x <- select(si.df, au, area_total, area_forest, area_pasture, area_sps
, stocking_rate, forest_reserves, distance, total_family_work, total_c
ontracted_work, labour, labourperhectare, milk_cows, milk_yield,  milk
perhectare)
summary(x)

##        au           area_total      area_forest      area_pasture
##  Min.   :  2.889   Min.   :  4.90   Min.   : 0.000   Min.   :  2.00
##  1st Qu.: 14.133   1st Qu.: 27.50   1st Qu.: 1.000   1st Qu.: 17.12
##  Median : 22.556   Median : 46.00   Median : 2.000   Median : 28.50
##  Mean   : 28.416   Mean   : 53.11   Mean   : 5.009   Mean   : 36.75
##  3rd Qu.: 34.556   3rd Qu.: 65.00   3rd Qu.: 6.250   3rd Qu.: 49.88
##  Max.   :148.444   Max.   :250.00   Max.   :48.500   Max.   :190.00
##                                     NA's   :3
##     area_sps        stocking_rate      forest_reserves       distance
##  Min.   : 0.0000   Min.   : 0.06349   Min.   :0.00000   Min.   :  161.8
##  1st Qu.: 0.0000   1st Qu.: 0.42859   1st Qu.:0.02809   1st Qu.:11776.1
##  Median : 0.0000   Median : 0.72288   Median :0.05810   Median :14876.6
##  Mean   : 0.6988   Mean   : 1.30052   Mean   :0.08943   Mean   :15365.9
##  3rd Qu.: 0.0000   3rd Qu.: 1.42989   3rd Qu.:0.12500   3rd Qu.:20299.4
##  Max.   :10.0000   Max.   :16.72381   Max.   :0.40000   Max.   :25536.8
##                                       NA's   :3
##  total_family_work total_contracted_work      labour
##  Min.   :  0.00    Min.   :   0.00       Min.   :   0.300
##  1st Qu.:  3.00    1st Qu.:   0.00       1st Qu.:   4.625
##  Median : 10.20    Median :   0.00       Median :  14.700
##  Mean   : 48.05    Mean   :  38.84       Mean   :  86.888
##  3rd Qu.: 25.60    3rd Qu.:   2.00       3rd Qu.:  33.500
##  Max.   :799.94    Max.   :2520.00       Max.   :2520.000
```

```
##
##  labourperhectare     milk_cows       milk_yield     milkperhectare
##  Min.   :  0.02222   Min.   : 1.00   Min.   :  1095   Min.   :  44.02
##  1st Qu.:  0.16954   1st Qu.: 7.00   1st Qu.:  9062   1st Qu.: 308.51
##  Median :  0.38158   Median :10.00   Median : 14600   Median : 511.00
##  Mean   :  3.42661   Mean   :11.27   Mean   : 19114   Mean   : 688.99
##  3rd Qu.:  1.33465   3rd Qu.:15.00   3rd Qu.: 25550   3rd Qu.: 847.93
##  Max.   :109.56522   Max.   :48.00   Max.   :105120   Max.   :3332.61
##
```

7.5.4 Summary of Key-Variables of Farmers without SPS

```
summary(select(NoSPS, au, area_total, area_forest, area_pasture, area_
sps, stocking_rate, forest_reserves, distance, total_family_work, tota
l_contracted_work, labour, labourperhectare, milk_cows, milk_yield,  m
ilkperhectare))
```

```
##        au            area_total      area_forest     area_pasture
##  Min.   :  4.933   Min.   :  4.90   Min.   : 0.00   Min.   :  2.00
##  1st Qu.: 14.000   1st Qu.: 26.62   1st Qu.: 1.00   1st Qu.: 17.19
##  Median : 22.189   Median : 48.00   Median : 2.00   Median : 28.75
##  Mean   : 25.772   Mean   : 53.46   Mean   : 5.15   Mean   : 37.71
##  3rd Qu.: 30.817   3rd Qu.: 65.00   3rd Qu.: 7.00   3rd Qu.: 50.00
##  Max.   :123.356   Max.   :250.00   Max.   :48.50   Max.   :190.00
##     area_sps  stocking_rate    forest_reserves      distance
##  Min.   :0   Min.   :0.1411   Min.   :0.00000   Min.   :  161.8
##  1st Qu.:0   1st Qu.:0.4432   1st Qu.:0.02809   1st Qu.:11663.2
##  Median :0   Median :0.7172   Median :0.06518   Median :14760.3
##  Mean   :0   Mean   :1.0711   Mean   :0.09334   Mean   :15055.6
##  3rd Qu.:0   3rd Qu.:1.1295   3rd Qu.:0.15930   3rd Qu.:19708.5
##  Max.   :0   Max.   :5.6000   Max.   :0.40000   Max.   :23024.2
##  total_family_work total_contracted_work     labour
##  Min.   :  0.00    Min.   :  0.000       Min.   :  0.30
##  1st Qu.:  3.00    1st Qu.:  0.000       1st Qu.:  5.80
##  Median : 11.85    Median :  0.000       Median : 15.60
##  Mean   : 50.66    Mean   :  9.484       Mean   : 60.15
##  3rd Qu.: 25.55    3rd Qu.:  2.000       3rd Qu.: 31.05
##  Max.   :799.94    Max.   :387.000       Max.   :799.94
##  labourperhectare     milk_cows       milk_yield     milkperhectare
##  Min.   : 0.02222   Min.   : 1.00   Min.   :  1095   Min.   :  44.02
##  1st Qu.: 0.17098   1st Qu.: 6.75   1st Qu.:  9125   1st Qu.: 310.68
##  Median : 0.38979   Median :10.00   Median : 14600   Median : 511.64
##  Mean   : 2.28159   Mean   :11.01   Mean   : 18412   Mean   : 667.69
##  3rd Qu.: 1.32697   3rd Qu.:15.00   3rd Qu.: 25550   3rd Qu.: 813.86
##  Max.   :40.84500   Max.   :48.00   Max.   :105120   Max.   :2555.00
```

7.5.5 Summary of Key-Variables of Farmers with SPS

```
summary(select(SPS, au, area_total, area_forest, area_pasture, area_sp
s, stocking_rate, forest_reserves, distance, total_family_work, total_
contracted_work, labour, labourperhectare, milk_cows, milk_yield,  mil
kperhectare))
```

```
##        au            area_total      area_forest      area_pasture
##  Min.   :  2.889   Min.   :  9.75   Min.   : 0.000   Min.   :  4.75
##  1st Qu.: 17.956   1st Qu.: 29.00   1st Qu.: 1.375   1st Qu.: 17.12
##  Median : 35.022   Median : 40.00   Median : 2.000   Median : 28.25
```

```
##  Mean   : 40.403   Mean   : 51.53   Mean   : 4.208   Mean   : 32.42  
##  3rd Qu.: 44.144   3rd Qu.: 69.00   3rd Qu.: 3.000   3rd Qu.: 36.12  
##  Max.   :148.444   Max.   :133.00   Max.   :30.000   Max.   :102.25  
##                                     NA's   :3                        
##     area_sps      stocking_rate      forest_reserves      distance    
##  Min.   : 0.500   Min.   : 0.06349   Min.   :0.00000   Min.   : 6341  
##  1st Qu.: 1.250   1st Qu.: 0.33296   1st Qu.:0.02842   1st Qu.:12820  
##  Median : 4.000   Median : 1.00764   Median :0.04026   Median :19714  
##  Mean   : 3.867   Mean   : 2.34061   Mean   :0.06724   Mean   :16772  
##  3rd Qu.: 4.500   3rd Qu.: 1.75084   3rd Qu.:0.05893   3rd Qu.:20891  
##  Max.   :10.000   Max.   :16.72381   Max.   :0.34884   Max.   :25537  
##                                      NA's   :3                        
##  total_family_work total_contracted_work     labour        
##  Min.   :  0.00    Min.   :   0.0        Min.   :   1.000  
##  1st Qu.:  4.00    1st Qu.:   0.0        1st Qu.:   4.125  
##  Median :  4.25    Median :   0.0        Median :   8.000  
##  Mean   : 36.19    Mean   : 171.9        Mean   : 208.121  
##  3rd Qu.: 25.41    3rd Qu.:   0.0        3rd Qu.:  42.625  
##  Max.   :370.00    Max.   :2520.0        Max.   :2520.000  
##                                                            
##  labourperhectare      milk_cows      milk_yield    milkperhectare  
##  Min.   :  0.03963   Min.   : 1.0   Min.   : 2555   Min.   : 128.4  
##  1st Qu.:  0.16555   1st Qu.: 8.0   1st Qu.: 8030   1st Qu.: 300.5  
##  Median :  0.33333   Median :12.0   Median :20075   Median : 486.7  
##  Mean   :  8.61735   Mean   :12.4   Mean   :22297   Mean   : 785.6  
##  3rd Qu.:  1.37617   3rd Qu.:14.5   3rd Qu.:27375   3rd Qu.: 894.2  
##  Max.   :109.56522   Max.   :35.0   Max.   :76650   Max.   :3332.6  
## 
```

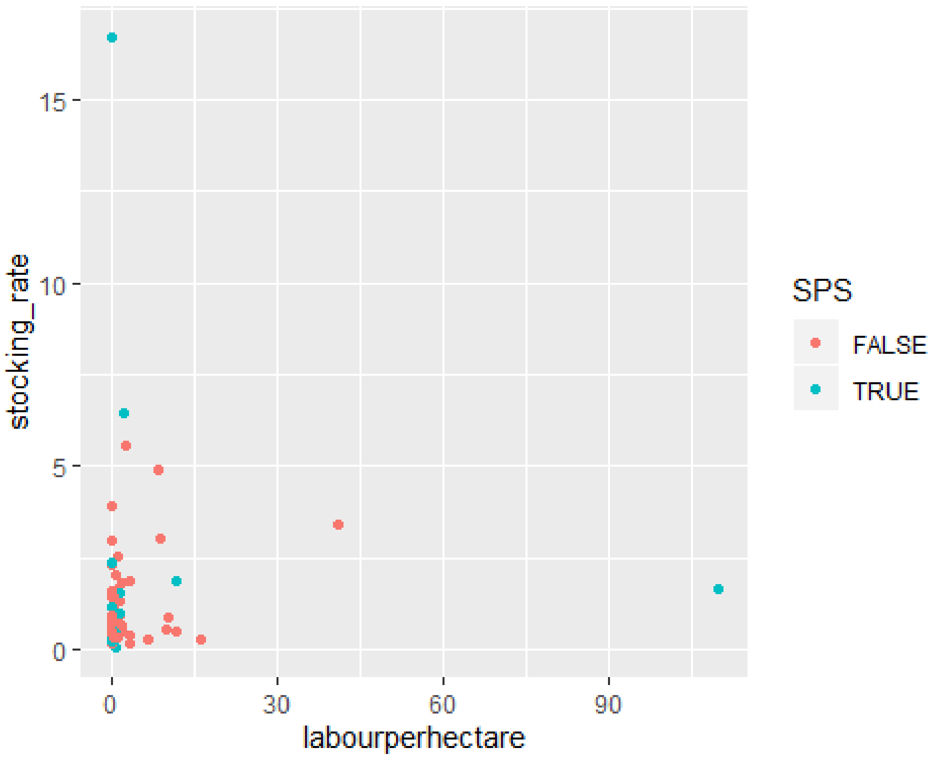
7.6 R-Code SQ1

```
library(tidyverse) # loading R packages
library(ggplot2)
load("Dataframes/si.df.rda") # Load Dataframe
si.df <- filter(si.df, land_type=="Lomerío (lomas, mesas y vallecitos"
 & SPS!="NA") # filtering data to only contain farms on landscape "hil
ls" and missing responses for SPS
```

7.6.1 Creating Scatterplotts

```
ggplot(data = si.df)+
  geom_point(mapping = aes(x=milkperhectare, y= distance, colour=SPS))
```


```
ggplot(data = si.df)+
  geom_point(mapping = aes(x=labourperhectare, y= stocking_rate, colou
r=SPS))
```



Stocking rates

7.6.2 Histograms and Q-Q Plots for Stocking Rates of Farmers without and with SPS

```
par(mfrow=c(2,2))
hist(si.df$stocking_rate[si.df$SPS==FALSE],breaks = 60, main="farmers
without SPS")
qqnorm(si.df$stocking_rate[si.df$SPS==FALSE], ylim = c(0,6))
qqline(si.df$stocking_rate[si.df$SPS==FALSE], ylim = c(0,6))
hist(si.df$stocking_rate[si.df$SPS==TRUE],breaks = 15, main="farmers w
ith SPS")
qqnorm(si.df$stocking_rate[si.df$SPS==TRUE], ylim = c(0,6))
qqline(si.df$stocking_rate[si.df$SPS==TRUE], ylim = c(0,6))
```

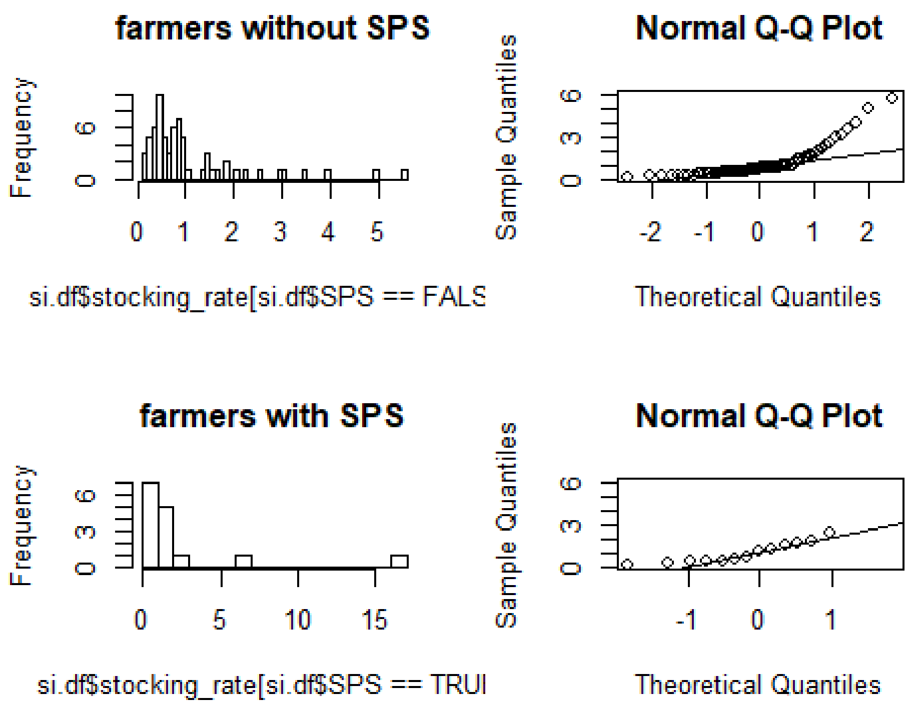


Figure 14: Histograms and Q-Q plots for stocking rates of farmers without and with SPS (own projection)

7.6.3 Log-Transformation of Stocking Rates

```
si.df$stocking_rate.log <- log(si.df$stocking_rate)
```

7.6.4 Histograms and Q-Q Plots of Log-Stocking Rates

```
par(mfrow=c(2,2))
hist(si.df$stocking_rate.log[si.df$SPS==FALSE], breaks = 60, main = "f
armers without SPS")
qqnorm(si.df$stocking_rate.log[si.df$SPS==FALSE], ylim = c(-3,3))
qqline(si.df$stocking_rate.log[si.df$SPS==FALSE], ylim = c(-3,3))
hist(si.df$stocking_rate.log[si.df$SPS==TRUE], breaks = 15, main="farm
ers with SPS")
qqnorm(si.df$stocking_rate.log[si.df$SPS==TRUE], ylim = c(-3,3))
qqline(si.df$stocking_rate.log[si.df$SPS==TRUE], ylim = c(-3,3))
```

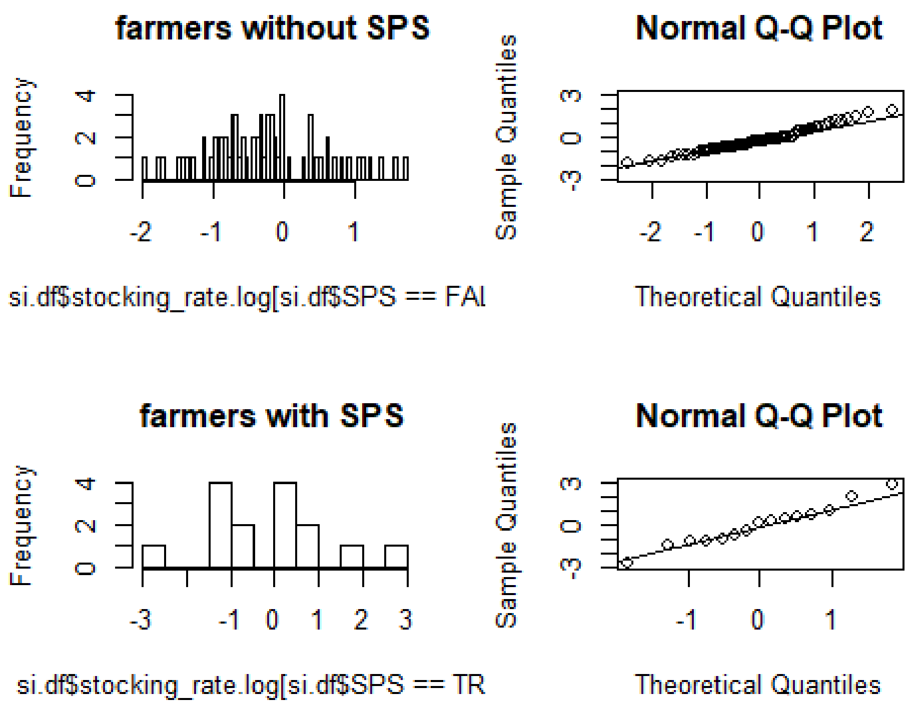


Figure 15: Histograms and Q-Q plots of log-stocking rates (own projection)

7.6.5 Boxplots of Stocking Rates of Farmers without and with SPS

```
ggplot(data=si.df)+
  geom_boxplot(mapping = aes(y=stocking_rate.log, x=SPS))
```

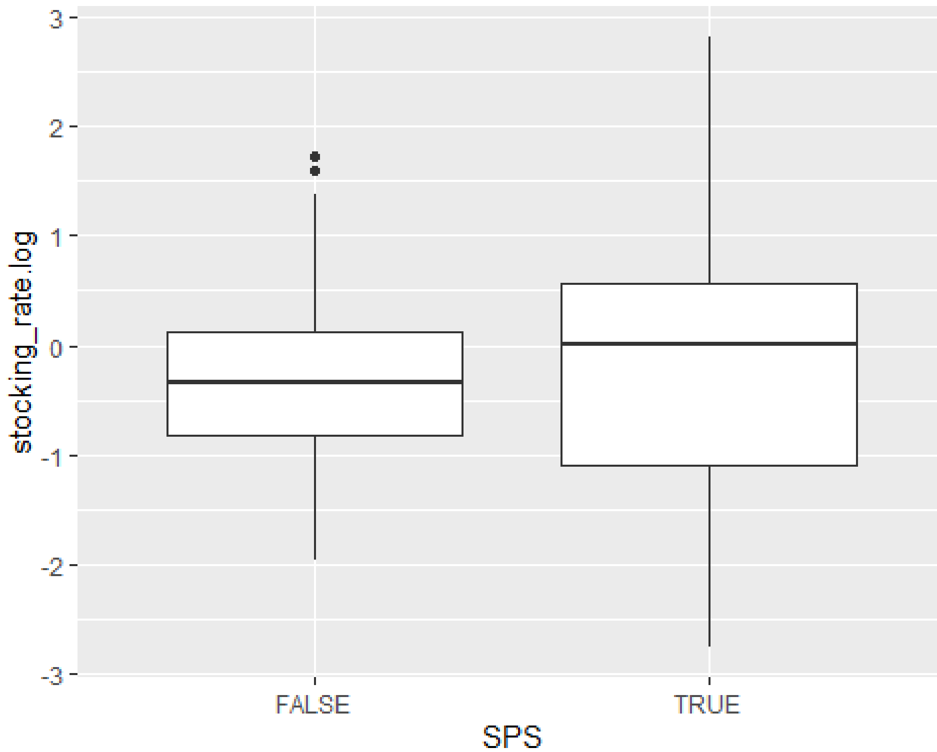


Figure 16: Boxplots of stocking rates of farmers without and with SPS (own projection)

7.6.6 Two-sided T-Test of Means of Log-Stocking Rates of Farmers without and with SPS

```
stock.t_test <- t.test(
  x=si.df$stocking_rate.log [si.df$SPS==FALSE],
  y=si.df$stocking_rate.log [si.df$SPS==TRUE])
stock.t_test

##
##  Welch Two Sample t-test
##
## data:  si.df$stocking_rate.log[si.df$SPS == FALSE] and si.df$stocki
ng_rate.log[si.df$SPS == TRUE]
## t = -0.48169, df = 16.172, p-value = 0.6365
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.9701064  0.6106179
## sample estimates:
##  mean of x  mean of y
## -0.2865579 -0.1068137
```

7.6.7 Transformation of Means of Log-Stocking Rates Back to Level Value

```
exp(stock.t_test$estimate)

## mean of x mean of y
## 0.7508436 0.8986931
```

7.6.8 Histograms and Q-Q plots of Milk Yields of Farmers without and with SPS

```
par(mfrow=c(2,2))
hist(si.df$milkperhectare[si.df$SPS==FALSE],breaks = 70, main="farmers
 without SPS")
qqnorm(si.df$milkperhectare[si.df$SPS==FALSE], ylim = c(-0,2500))
qqline(si.df$milkperhectare[si.df$SPS==FALSE], ylim = c(-0,2500))
hist(si.df$milkperhectare[si.df$SPS==TRUE],breaks = 15, main="farmers
with SPS")
qqnorm(si.df$milkperhectare[si.df$SPS==TRUE], ylim = c(-0,2500))
qqline(si.df$milkperhectare[si.df$SPS==TRUE], ylim = c(-0,2500))
```

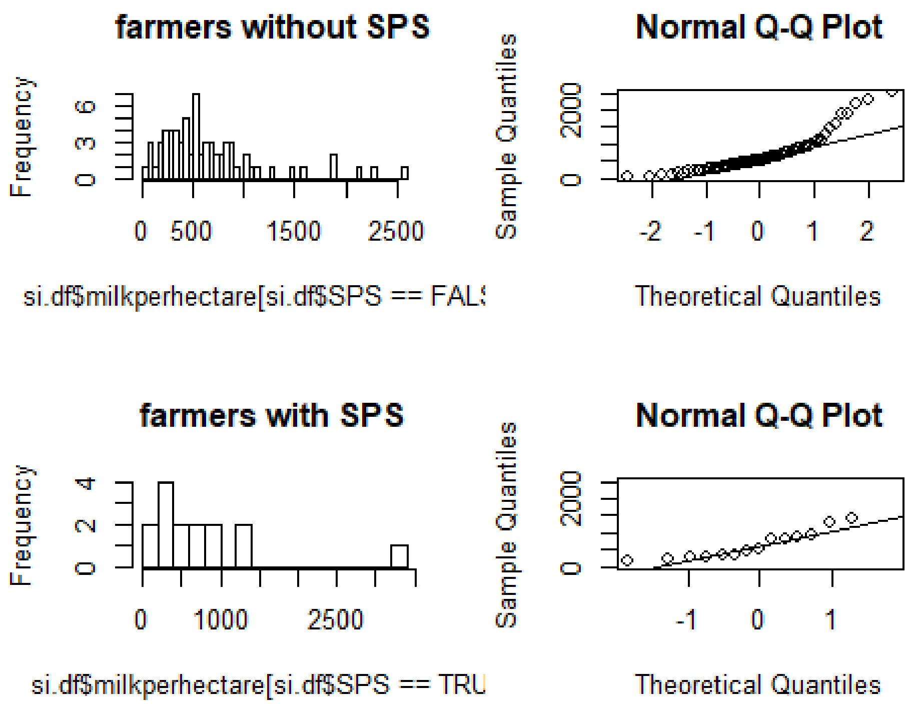


Figure 17: Histograms and Q-Q plots of milk yields of farmers without and with SPS (own projection)

7.6.9 Log-Transformation of Milk Yields

```
si.df$milkperhectare.log <- log(si.df$milkperhectare)
```

7.6.10 Histograms and Q-Q Plots of Log-Milk Yields

```
par(mfrow=c(2,2))
hist(si.df$milkperhectare.log[si.df$SPS==FALSE], breaks = 70, main = "
farmers without SPS")
qqnorm(si.df$milkperhectare.log[si.df$SPS==FALSE], ylim = c(4,8))
qqline(si.df$milkperhectare.log[si.df$SPS==FALSE], ylim = c(4,8))
hist(si.df$milkperhectare.log[si.df$SPS==TRUE], breaks = 15, main="far
mers with SPS")
qqnorm(si.df$milkperhectare.log[si.df$SPS==TRUE], ylim = c(4,8))
qqline(si.df$milkperhectare.log[si.df$SPS==TRUE], ylim = c(4,8))
```

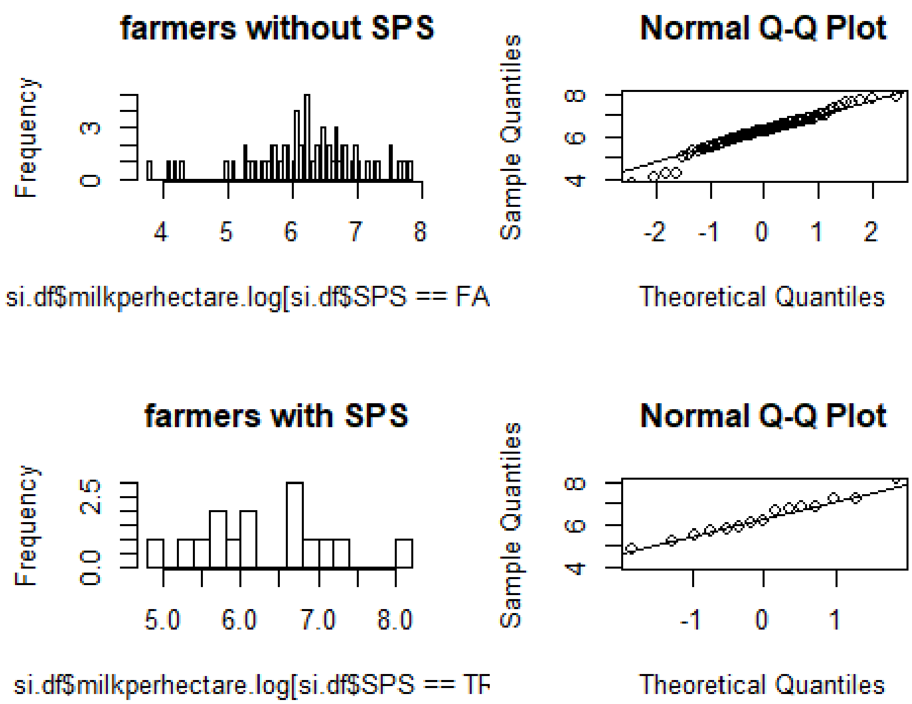


Figure 18: Histograms and Q-Q plots of log-milk yields (own projection)

7.6.11 Boxplots of Log-Milk Yields

```
ggplot(data=si.df)+
  geom_boxplot(mapping = aes(y=milkperhectare.log, x=SPS))
```

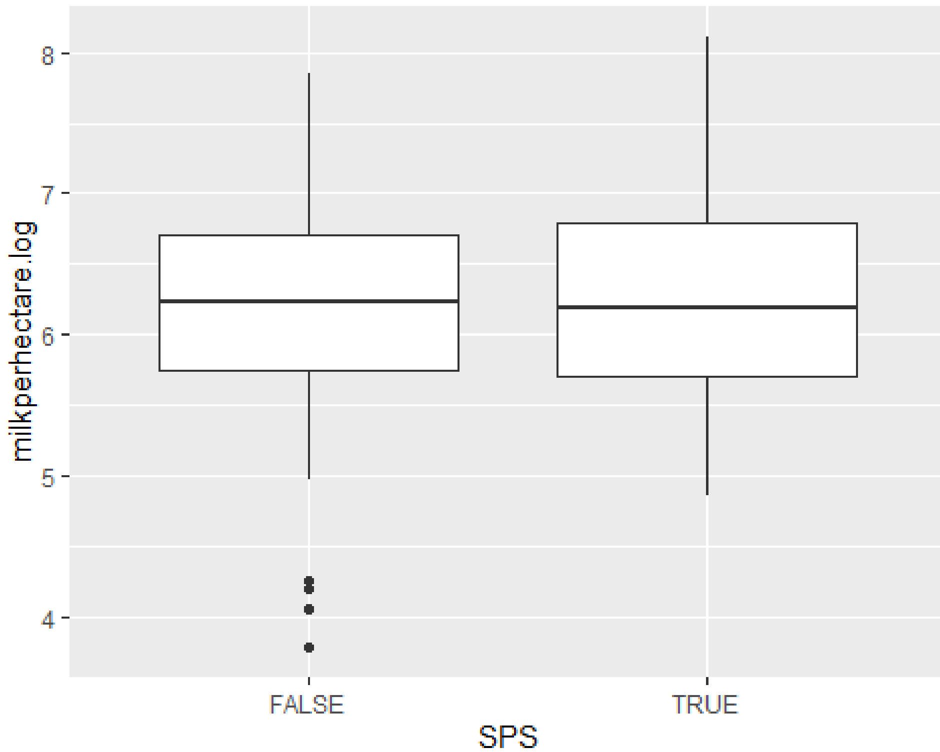


Figure 19: Boxplots of log milk yield (own projection)

7.6.12 T-Test Comparing Mean Log-Milk Yields per Hectare of Farmers with and without SPS

```
my.t_test <- t.test(
  x=si.df$milkperhectare.log[si.df$SPS==FALSE],
  y=si.df$milkperhectare.log[si.df$SPS==TRUE])
my.t_test

##
##  Welch Two Sample t-test
##
## data:  si.df$milkperhectare.log[si.df$SPS == FALSE] and si.df$milkp
erhectare.log[si.df$SPS == TRUE]
## t = -0.4109, df = 20.246, p-value = 0.6855
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.6136649  0.4115578
## sample estimates:
## mean of x mean of y
##  6.200096  6.301150
```

7.6.13 Transformation of Means of Log-Milk Yields Back to Level Value

```
exp(my.t_test$estimate)

## mean of x mean of y
##  492.7965  545.1984
```

7.6.14 Histograms and Q-Q Plot of Labour Days of Farmers without and with SPS

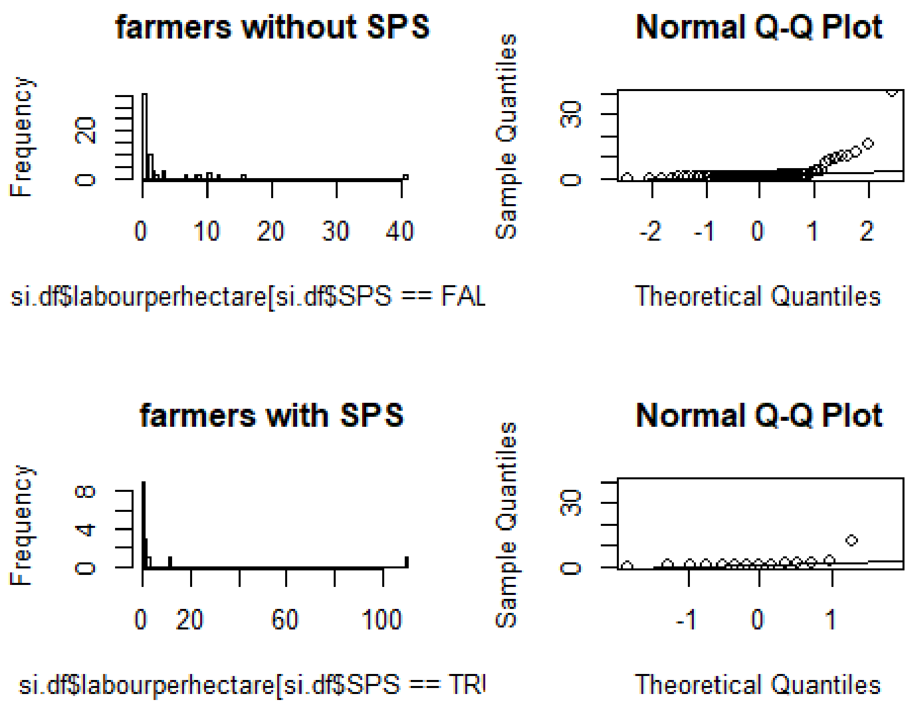


Figure 20: Histograms and Q-Q plot of labour days of farmers without and with SPS (own projection)

7.6.15 Log-Transformation of Labour Days

```
si.df$labourperhectare.log <- log(si.df$labourperhectare+0.01)
```

7.6.16 Histograms and Q-Q Plots of Log-Labour Days

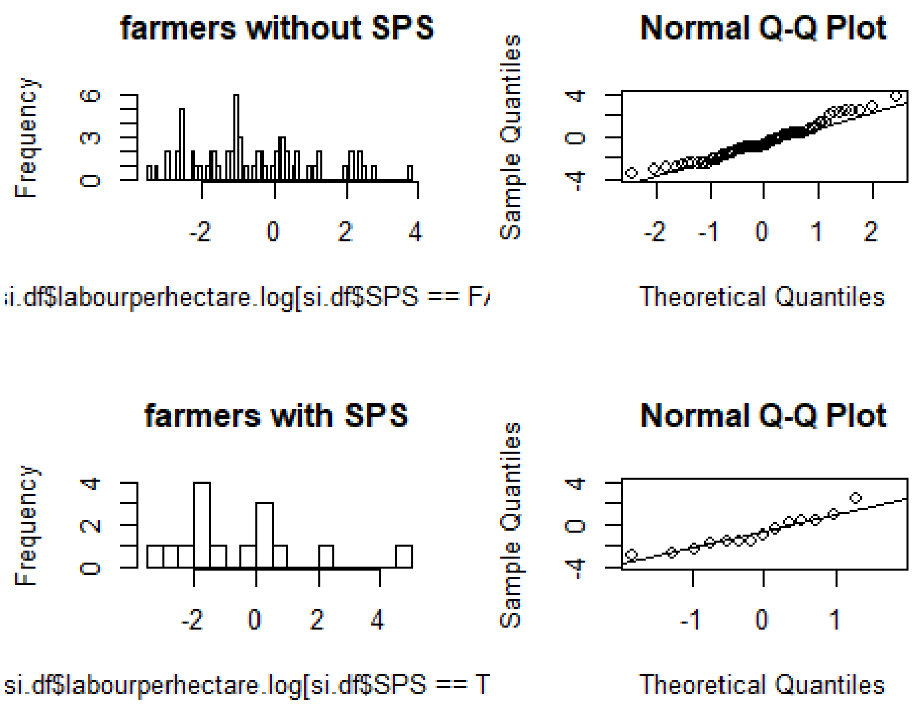


Figure 21: Histograms and Q-Q plots of log-labour days (own projection)

7.6.17 Boxplot of Log-Labour Days

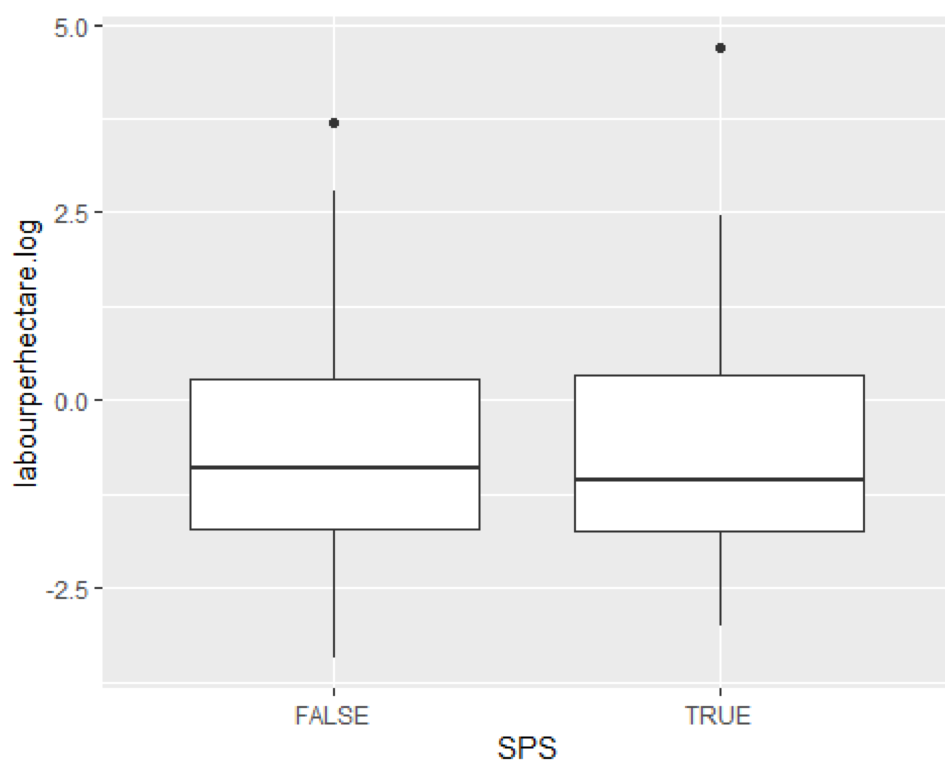


Figure 22: Boxplot of log-labour days (own projection)

7.6.18 T-Test Comparing Mean Log-Labour Hours per Hectare of Farmers without and with SPS

```
lh.t_test <- t.test(
  x=si.df$labourperhectare.log[si.df$SPS==FALSE],
  y=si.df$labourperhectare.log[si.df$SPS==TRUE])
lh.t_test

##
##  Welch Two Sample t-test
##
## data:  si.df$labourperhectare.log[si.df$SPS == FALSE] and si.df$lab
ourperhectare.log[si.df$SPS == TRUE]
## t = -0.13306, df = 17.937, p-value = 0.8956
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -1.272137  1.120631
## sample estimates:
##  mean of x  mean of y
## -0.5760283 -0.5002750
```

7.6.19 Transformation of Means of Log-Labour Days Back to Level Values

```
exp(lh.t_test$estimate)-0.01

## mean of x mean of y
## 0.5521266 0.5963639
```

7.6.20 Histograms and Q-Q Plots of Distance of Farmers without and with SPS

```
par(mfrow=c(2,2))
hist(si.df$distance[si.df$SPS==FALSE],breaks = 70, main="farmers witho
ut SPS")
qqnorm(si.df$distance[si.df$SPS==FALSE], ylim = c(-0,25000))
qqline(si.df$distance[si.df$SPS==FALSE], ylim = c(-0,25000))
hist(si.df$distance[si.df$SPS==TRUE],breaks = 15, main="farmers with S
PS")
qqnorm(si.df$distance[si.df$SPS==TRUE], ylim = c(-0,25000))
qqline(si.df$distance[si.df$SPS==TRUE], ylim = c(-0,25000))
```

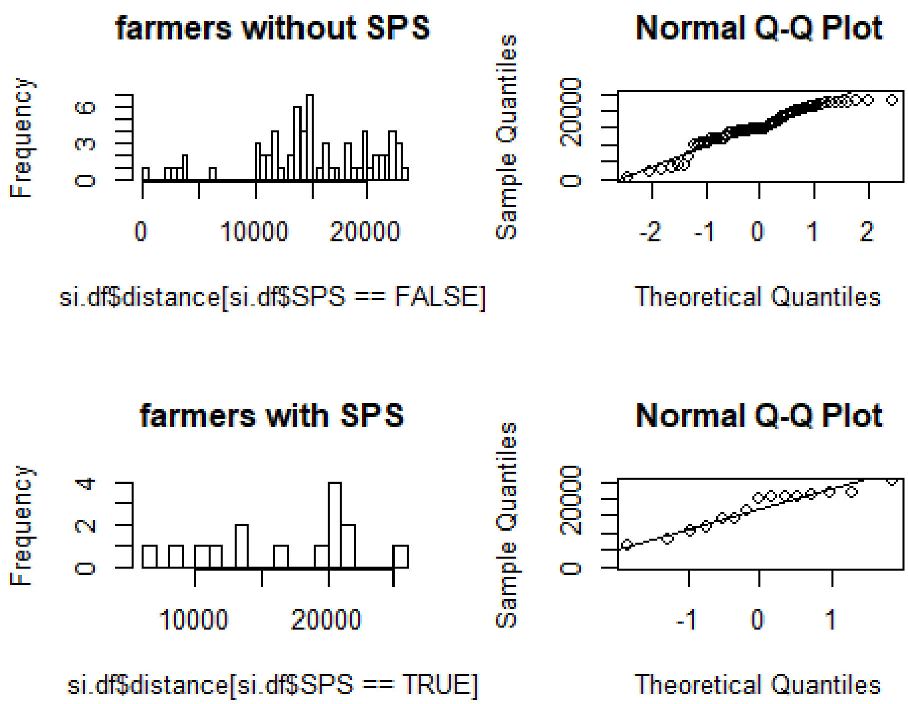


Figure 23: Histograms and Q-Q plots of distance of farmers without and with SPS (own projection)

7.6.21 Boxplots of Distance

```
ggplot(data=si.df)+
  geom_boxplot(mapping = aes(y=distance, x=SPS))
```

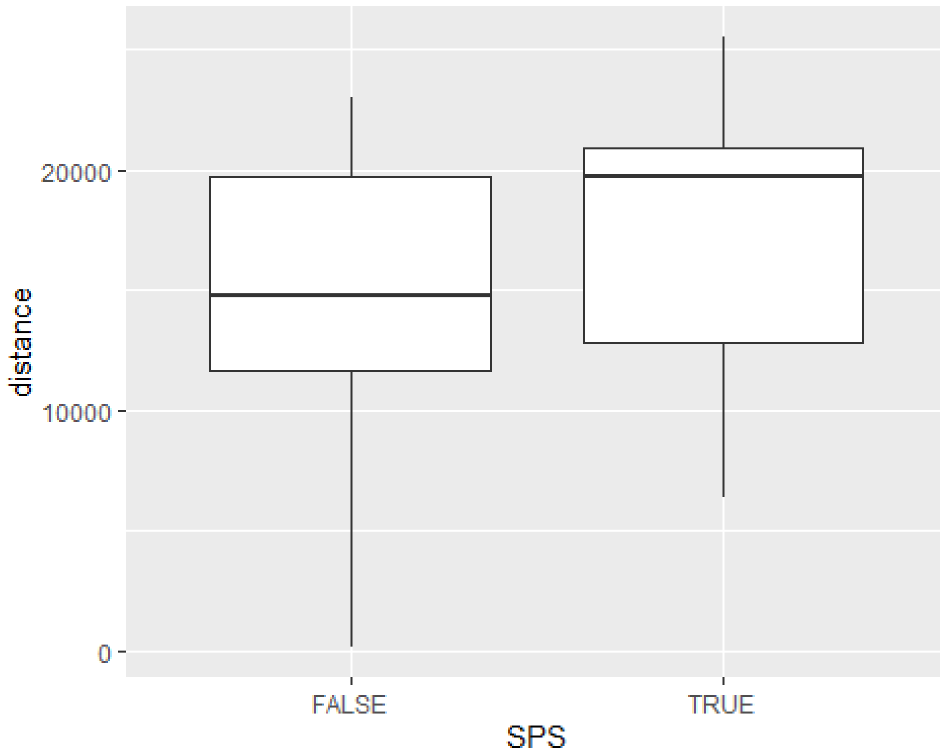


Figure 24: Boxplots of distance (own projection)

7.6.22 T-test Comparing Mean Distance of Farmers without and with SPS

```
d.t_test <- t.test(
  x=si.df$distance[si.df$SPS==FALSE],
  y=si.df$distance[si.df$SPS==TRUE])
d.t_test

##
##  Welch Two Sample t-test
##
## data:  si.df$distance[si.df$SPS == FALSE] and si.df$distance[si.df$
SPS == TRUE]
## t = -1.0514, df = 20.245, p-value = 0.3055
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -5120.033  1686.631
## sample estimates:
## mean of x mean of y
##  15055.63  16772.33
```

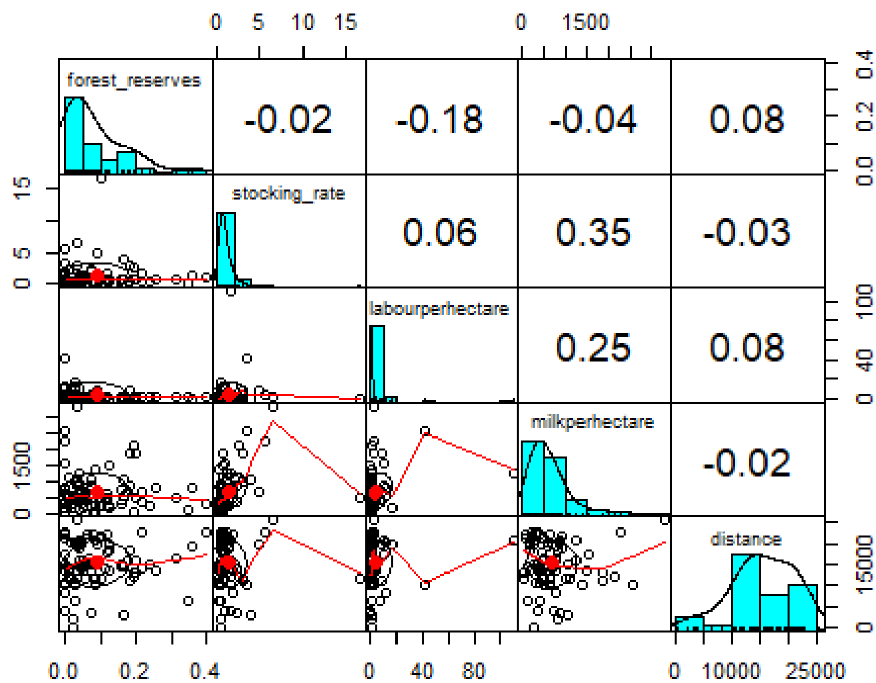
7.7 R-Code SQ2

7.7.1 Loading R Packages and Dataframe

```
library(tidyverse)
library(ggplot2)
library(psych)
library(heplots)
load("Dataframes/si.df.rda")
```

7.7.2 Scatterplots, Histograms and Correlations of Forest Reserves, Stocking Rates, Annual Milk Yields per Hectare, Annual Labour Days per Hectare and Distances to Highway

```
model.var <- c(12,32, 36, 37, 14) # forest_reserves,stocking rate, mil
kperhectare, labourperhectare, distance
pairs.panels(si.df[,model.var],
             gap=0,
             bg=c("red")[si.df$SPS],
             pch = 21)
```

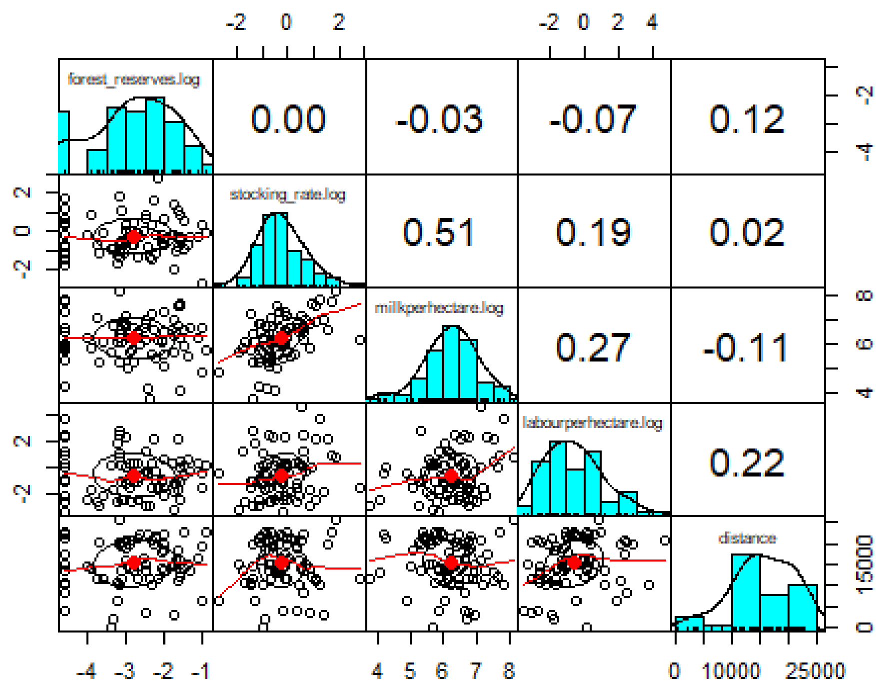


7.7.3 Log-Transformation of Forest Reserves

```
si.df$forest_reserves.log <- log(si.df$forest_reserves+0.01) ## +0.01
to avoid infinitifs
```

7.7.4 Scatterplots, Histograms and Correlations of Log-Forest Reserves, Log-Stocking Rates, Log-Annual Milk Yields per Hectare, Log-Annual Labour Days per Hectare and Distances to Highway

```
log.var <- c(44,41:43,14) # forest_reserves.log,stocking_rate.log , mi
lkperhectare.log, labourperhectare.log, distance
pairs.panels(si.df[,log.var],
             gap=0,
             bg=c("red", "green")[si.df$SPS],
             pch = 21)
```



7.7.5 Calculating Mahalanobis Distance of Log-Stocking Rates, Log-Milk Yields and Log-Labour Days

```
si.df<-si.df[!is.na(si.df$forest_reserves.log),] # remove NA in forest
_reserves.log
si.mhlnbs_outl <- mahalanobis(si.df[,c(41:43)],colMeans(si.df[,c(41:43
)]),cov(si.df[,c(41:43)]))
# Calculated Mahalanobis distances
si.df$mhlnbs <- round(si.mhlnbs_outl,3) #Add to dataframe
```

7.7.6 Q-Q Plot of Mahalanobis Distance and Theoretic Chi-Square Quantiles

```
qqPlot(si.df$mhlnbs, distribution = "chisq", df=3, envelope = FALSE, i
d=FALSE)
```

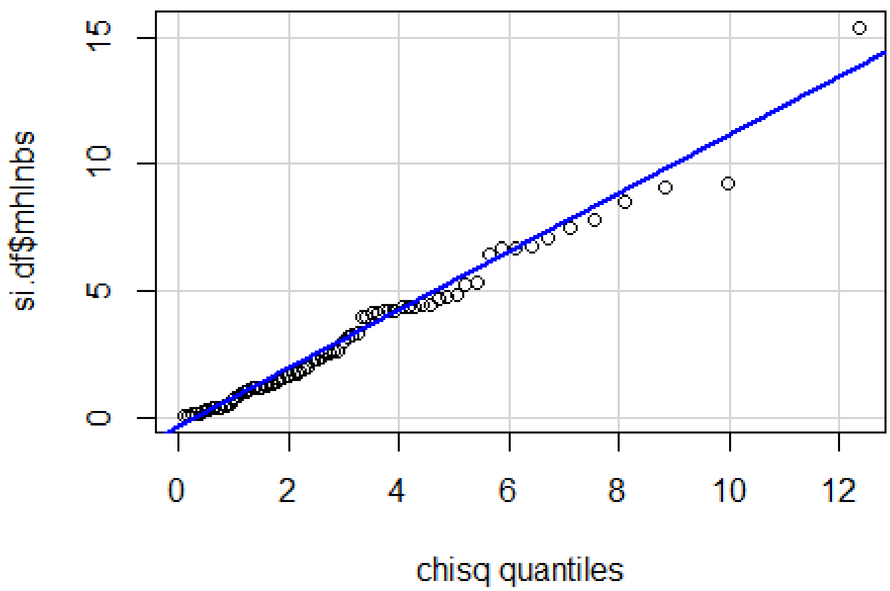


Figure 25: Q-Q plot of Mahalanobis distance and theoretic Chi-square quantiles (own projection)

7.7.7 Outlier Definition as Logic Variable in Dataframe

```
outlier <- 5.5
si.df$outlier_mhlnbs <- ifelse(si.df$mhlnbs > outlier, TRUE, FALSE)
summary(si.df$outlier_mhlnbs)

##    Mode   FALSE    TRUE
## logical      69      11
```

7.7.8 Key-Variables of Identified Outliers

```
##    id_house   SPS stocking_rate labourperhectare milkperhectare mhlnbs
## 1       B18 FALSE    0.59707602       0.07000000       57.63158  8.491
## 2       B25  TRUE    6.45410628       2.34782609     3332.60870  6.744
## 3       B28 FALSE    0.31827957       1.06451613       70.64516  6.407
## 4       B30 FALSE    0.44444444       0.64242424       66.36364  6.704
## 5       E14 FALSE    0.25964444      15.99879997      197.10000  7.823
## 6       E15 FALSE    4.92753623       8.49826060      698.26087  6.700
## 7       E20 FALSE    3.44444444      40.84500000     2555.00000  9.236
## 8       E23  TRUE    0.06349206       0.63340659      128.35165  7.455
## 9       G32  TRUE   16.72380952       0.19047619      486.66667 15.386
## 10      G35 FALSE    0.24567281       0.04020101       44.02010  9.048
## 11      G38  TRUE    0.23386243       0.19047619     1390.47619  7.062
```

7.7.9 Scatterplots of Mahalanobis Distance and Milk Yields, Labour Days and Stocking Rates

```
labs <- c("FALSE"="SPS=FALSE", "TRUE"="SPS=TRUE")
par(mfrow=c(3,1))
ggplot(data = si.df, mapping = aes(x=mhlnbs, y= milkperhectare))+
```

```
  geom_point(color="blue")+
  geom_vline(xintercept = outlier)+
  facet_wrap(~SPS, dir = "v", labeller = labeller(SPS=labs))+
   coord_flip()+
  geom_text(aes(x=mhlnbs, y= milkperhectare, label=ifelse(mhlnbs>7,as.
character(id_house),'')),hjust=0,vjust=0)
```

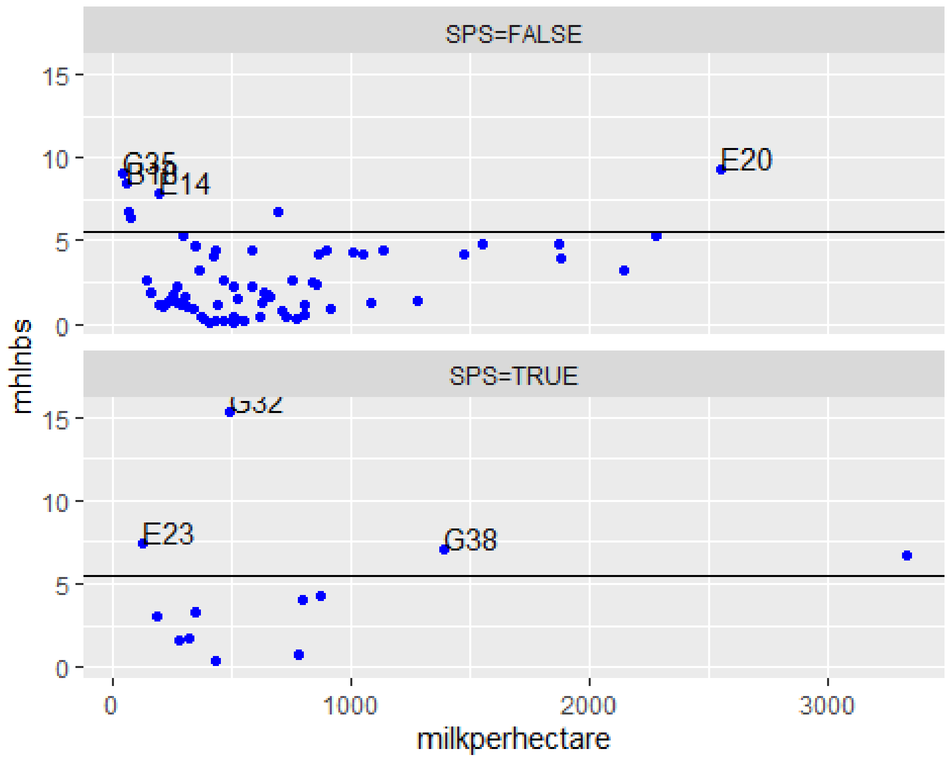


Figure 26: Scatterplots of Mahalanobis distance and milk yields (own projection)

```
ggplot(data = si.df,mapping = aes(x=mhlnbs, y= labourperhectare))+
  geom_point( color="blue")+
  geom_vline(xintercept = outlier)+
  facet_wrap(~SPS, dir = "v", labeller = labeller(SPS=labs))+
  coord_flip()+
  geom_text(aes(x=mhlnbs, y= labourperhectare, label=ifelse(mhlnbs>7,a
s.character(id_house),'')),hjust=0,vjust=0)
```

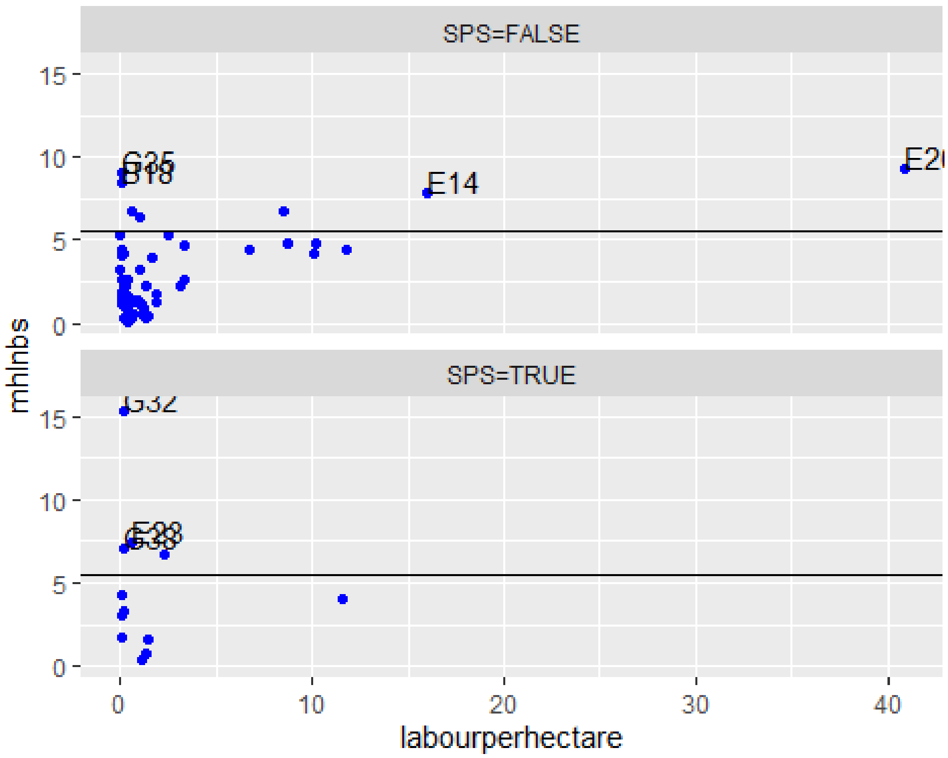


Figure 27: Scatterplots of Mahalanobis distance and labour per hectare (own projection)

```
ggplot(data = si.df,mapping = aes(x=mhlnbs, y= stocking_rate))+
  geom_point( color="blue")+
  geom_vline(xintercept = outlier)+
  facet_wrap(~SPS, dir = "v", labeller = labeller(SPS=labs))+
  coord_flip()+
  geom_text(aes(x=mhlnbs, y= stocking_rate, label=ifelse(mhlnbs>7,as.c
haracter(id_house),'')),hjust=0,vjust=0)
```

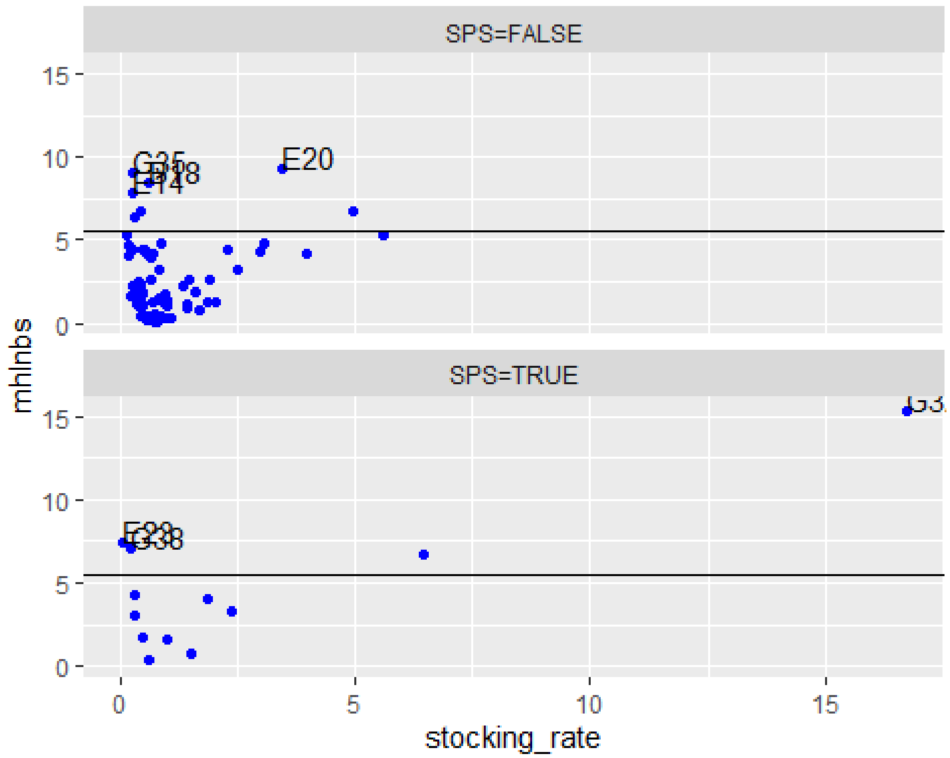


Figure 28: Scatterplots of Mahalanobis distance and stocking rates (own projection)

7.7.10 Removing Outliers from Dataframe

```
si.df <- filter(si.df, outlier_mhlnbs==FALSE)
```

7.7.11 Multiple Linear Regression Model

```
fr_multi_reg <- lm(forest_reserves.log ~ stocking_rate.log+milkperhect
are.log+labourperhectare.log+SPS+distance, data = si.df)
summary(fr_multi_reg)

##
## Call:
## lm(formula = forest_reserves.log ~ stocking_rate.log + milkperhecta
re.log +
##     labourperhectare.log + SPS + distance, data = si.df)
##
## Residuals:
##     Min       1Q   Median       3Q      Max
## -2.6089 -0.5270  0.1216  0.7052  1.5487
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)          -4.143e+00  1.697e+00  -2.441   0.0175 *
## stocking_rate.log     1.117e-01  1.945e-01   0.574   0.5677
## milkperhectare.log    1.121e-01  2.434e-01   0.460   0.6468
## labourperhectare.log -2.968e-02  8.934e-02  -0.332   0.7408
## SPSTRUE              -7.252e-01  4.026e-01  -1.801   0.0764 .
## distance              4.881e-05  2.433e-05   2.006   0.0492 *
```

```
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.053 on 63 degrees of freedom
## Multiple R-squared:  0.1038, Adjusted R-squared:  0.03264
## F-statistic: 1.459 on 5 and 63 DF,  p-value: 0.216
```

7.7.12 Q-Q Plot of Errorterms and Theoretical Quantiles

```
qqPlot(fr_multi_reg)
```

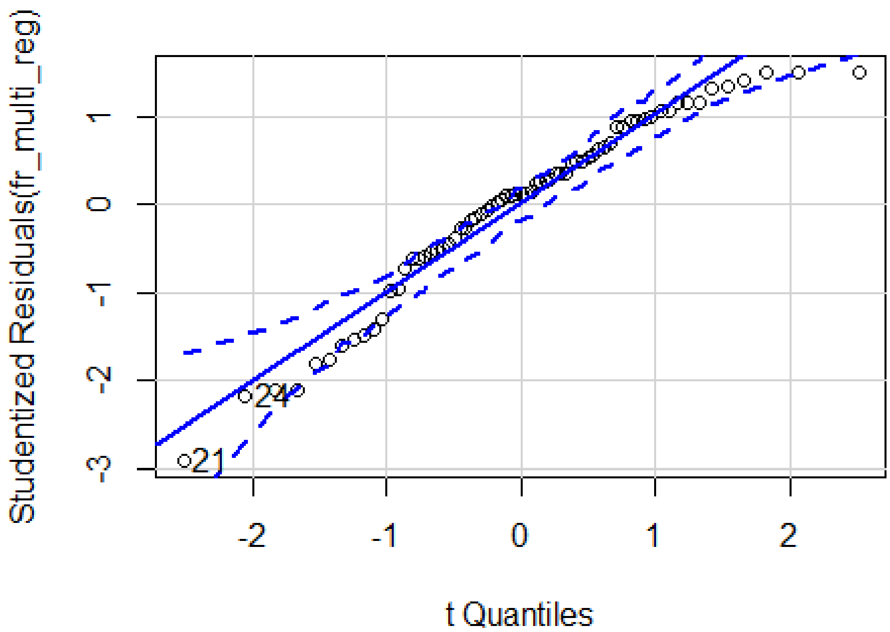


Figure 29: Q-Q plot of errorterms and theoretical quantiles (own projection)

```
## [1] 21 24
```

7.7.13 Variable Selection by Comparing AIC

```
step(fr_multi_reg)
```

```
## Start:  AIC=12.83
## forest_reserves.log ~ stocking_rate.log + milkperhectare.log +
##     labourperhectare.log + SPS + distance
##
##                        Df Sum of Sq    RSS    AIC
## - labourperhectare.log  1    0.1224 69.956 10.950
## - milkperhectare.log    1    0.2350 70.069 11.060
## - stocking_rate.log     1    0.3658 70.200 11.189
## <none>                              69.834 12.829
## - SPS                   1    3.5967 73.430 14.294
## - distance              1    4.4602 74.294 15.101
##
```

```
## Step:  AIC=10.95
## forest_reserves.log ~ stocking_rate.log + milkperhectare.log +
##     SPS + distance
##
##                      Df Sum of Sq    RSS     AIC
## - milkperhectare.log  1    0.1849 70.141  9.1316
## - stocking_rate.log   1    0.3482 70.304  9.2921
## <none>                            69.956 10.9495
## - SPS                 1    3.5618 73.518 12.3761
## - distance            1    4.3623 74.318 13.1234
##
## Step:  AIC=9.13
## forest_reserves.log ~ stocking_rate.log + SPS + distance
##
##                     Df Sum of Sq    RSS     AIC
## - stocking_rate.log  1    0.8739 71.015  7.9860
## <none>                           70.141  9.1316
## - SPS                1    3.8717 74.013 10.8390
## - distance           1    4.1821 74.323 11.1278
##
## Step:  AIC=7.99
## forest_reserves.log ~ SPS + distance
##
##            Df Sum of Sq    RSS    AIC
## <none>                  71.015 7.9860
## - SPS       1    3.7371 74.752 9.5247
## - distance  1    3.8951 74.910 9.6704

##
## Call:
## lm(formula = forest_reserves.log ~ SPS + distance, data = si.df)
##
## Coefficients:
## (Intercept)      SPSTRUE     distance
##  -3.366e+00   -7.310e-01    4.348e-05
```

7.7.14 AIC-Optimized Model

```
fr_sps_distance_reg <- lm(forest_reserves.log ~ SPS + distance, data =
 si.df)
summary(fr_sps_distance_reg)

##
## Call:
## lm(formula = forest_reserves.log ~ SPS + distance, data = si.df)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -2.2400 -0.4756  0.1313  0.7646  1.5256
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) -3.366e+00  3.644e-01  -9.237 1.65e-13 ***
```

```
## SPSTRUE     -7.310e-01  3.922e-01  -1.864   0.0668 .
## distance     4.348e-05  2.285e-05   1.903   0.0615 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.037 on 66 degrees of freedom
## Multiple R-squared:  0.08861,    Adjusted R-squared:  0.06099
## F-statistic: 3.209 on 2 and 66 DF,  p-value: 0.0468
```

7.7.15 Leaving Out Single Observations to See Reflection on Estimators

```
head(dfbeta(fr_sps_distance_reg), n=10L)
```

```
##      (Intercept)       SPSTRUE      distance
## 1   0.0174352876 -0.0156254842 -1.086302e-07
## 2   0.0142237193 -0.0109759961 -1.949388e-07
## 3   0.0034911363 -0.0035297981  2.320605e-09
## 4   0.0387364945 -0.0226684591 -9.644552e-07
## 5   0.0220584842 -0.0223410769  1.696212e-08
## 6  -0.0310743995  0.0314724957 -2.389501e-08
## 7   0.0079509393 -0.0173771386  5.657908e-07
## 8  -0.0037058362  0.0027592341  5.681811e-08
## 9  -0.0009173393  0.0005357745  2.290275e-08
## 10  0.0184703077 -0.0165615861 -1.145676e-07
```

7.7.16 Q-Q Plot of Errorterms of AIC-Optimized Linear Model and Theoretical Quantiles

```
qqPlot(fr_sps_distance_reg)
```

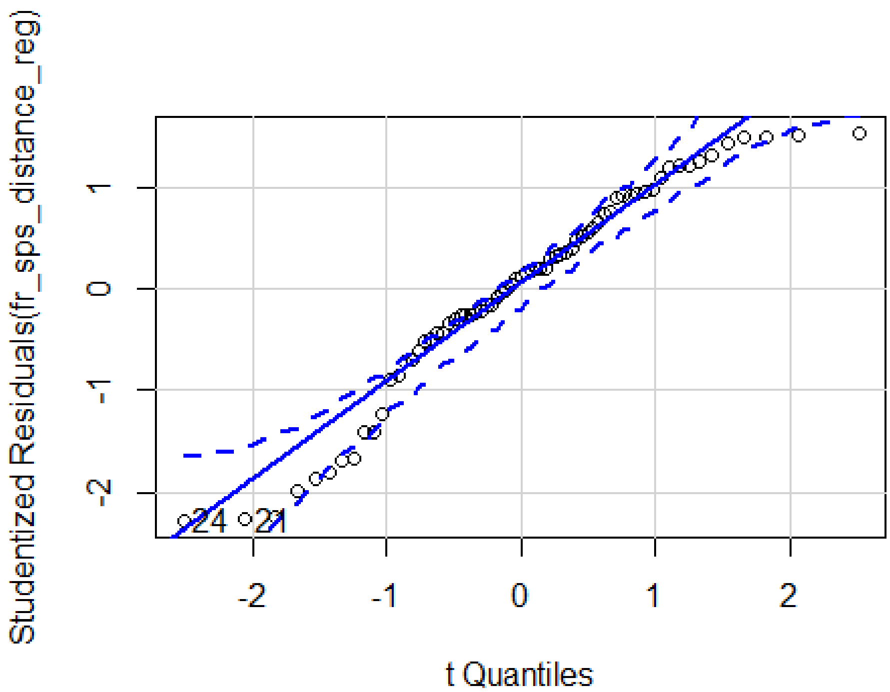


Figure 30: Q-Q plot of errorterms of AIC optimized linear model and theoretical quantiles (own projection)

```
## [1] 21 24
```

7.7.17 Boxplots of Log-Forest Reserves of Farmers without and with SPS

```
ggplot(data = si.df, mapping=aes(y=forest_reserves.log, x=SPS))+
  geom_boxplot()
```

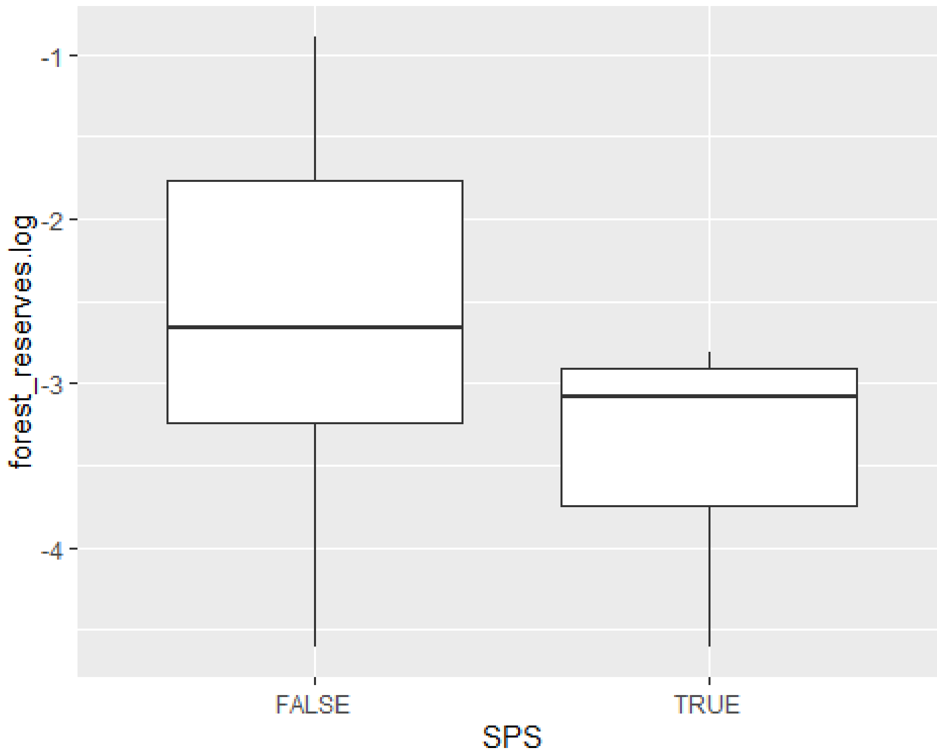


Figure 31: Boxplots of log-forest reserves of farmers without and with SPS (own projection)

7.7.18 One-sided T-Test of Mean Log-Forest Reserves of Farmers without and with SPS

```
fr_ttest <- t.test(x=si.df$forest_reserves.log[si.df$SPS==FALSE],
       y=si.df$forest_reserves.log[si.df$SPS==TRUE], alternative = "gr
eater"
       )
fr_ttest

##
##  Welch Two Sample t-test
##
## data:  si.df$forest_reserves.log[si.df$SPS == FALSE] and si.df$fore
st_reserves.log[si.df$SPS == TRUE]
## t = 2.4577, df = 13.252, p-value = 0.01424
## alternative hypothesis: true difference in means is greater than 0
## 95 percent confidence interval:
##  0.1829738       Inf
## sample estimates:
## mean of x mean of y
## -2.720532 -3.372854
```

7.7.19 Transformation of Mean Log-Forest Reserves Back to Level Values

```
exp(fr_ttest$estimate)-0.01

##  mean of x  mean of y
## 0.05583974 0.02429162
```