Chapter 6 Profile of Small-Scale Rubber Sector in Southeast Vietnam: Evidence Using the Survey Data

6.1 Introduction

This chapter assesses a profile of the small-scale rubber sector in Southeast Vietnam, relating to site-specific characteristics and household-specific characteristics. Site-specific characteristics include agro-ecological and socio-economic conditions of the study area. This chapter answers the fourth and fifth questions: How vulnerable are rubber farmer households to climate change? and How do rubber farmers perceive climate change and its effects? It finds relationships between these factors to consolidate findings of farmer households' vulnerability, perception and adaptation to climate change in this chapter and the next chapters.

The farm-level data used in this chapter were obtained through field surveys from January to April 2014 in the three provinces of Southeast Vietnam, using a structured questionnaire. The study area is considered to be representative of rubber cultivation in Southeast Vietnam.

Information on farm households that grow rubber trees in the study area was collected through surveys. Questionnaire responses revealed the institutional contexts, socio-economic conditions, and agro-environments in the study area; as well as demographic and farm characteristics of rubber farm households. The information indicated rubber farmer households' vulnerability, their perception and adaptation to climate change and it provided an overall assessment of rubber cultivation prospects from growers' points of view in the study area. Statistical analyses were undertaken in a systematic way, starting by describing results and identifying their significance.

This chapter is organised as follows. Sections 6.2–6.9 describe and compare the farm-level data consisting of (1) latex yield, (2) institutional factors, (3) socio-economic variables, (4) agro-environment features, (5) demographic characteristics, (6) farm characteristics, (7) farmer households' vulnerability to and (8) their perception of climate change and variability. Section 6.10 discusses and concludes this chapter.

Most of the survey respondents were household heads[48] (85.6 per cent). Summary statistics of rubber farm household characteristics are presented in Appendix 1. The characteristics of a household head

[48] A household head is considered as a key decision maker of the household in agricultural activities. Normally, the respondent tells the interviewer who is the household head. This household head may

provide proxy variables for that rubber farm household's characteristics. Hence, results from this study are expected to be representative of rubber farming in Southeast Vietnam.

6.2 Farm-Level Latex Yield

This section tests whether latex yield of rubber farm households is statistically different across the three provinces.

Table 6.1: Summary statistics of yield in the three provinces

No.	Description	Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Mean latex yield (tonnes/ha)	2.04	2.24	1.66	2.16
2	Median latex yield (tonnes/ha)	2.0	2.3	1.5	2.2
3	Skewness and Kurtosis test for normality of yield	8.21* *(N=405)*			
4	Wilcoxon signed-rank test for median latex yield against the hypothesised value of 1.65 tonnes/ha *z*-statistic	9.82**			
5	Kruskal-Wallis equality-of-populations' rank test of median yield	65.60**			
	Rank sum		34,328 *(N=146)*	15,470 *(N=119)*	32,417 *(N=140)*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

In Table 6.1, mean latex yield in the survey area is just over 2 tonnes/ha. The Skewness and Kurtosis test indicates that *yield* among the three provinces is not normally distributed ($p < 0.05$). The Kruskal-Wallis test was used to test for three independent-samples equality of populations' rank of median yield. Statistical differences are found in median yields across the three provinces. This means the null hypothesis can be rejected ($p < 0.01$). Binh Phuoc has the highest rank of median latex yield, followed by Tay Ninh and Dong Nai. These rankings are consistent compared to their rankings in Table 5.1. However, statistically significant differences in median yields across the three provinces are not found in the secondary data (Table 5.2).

be different from a household head whose name is written in the demographic book, depending on his or her decision-making power in the household.

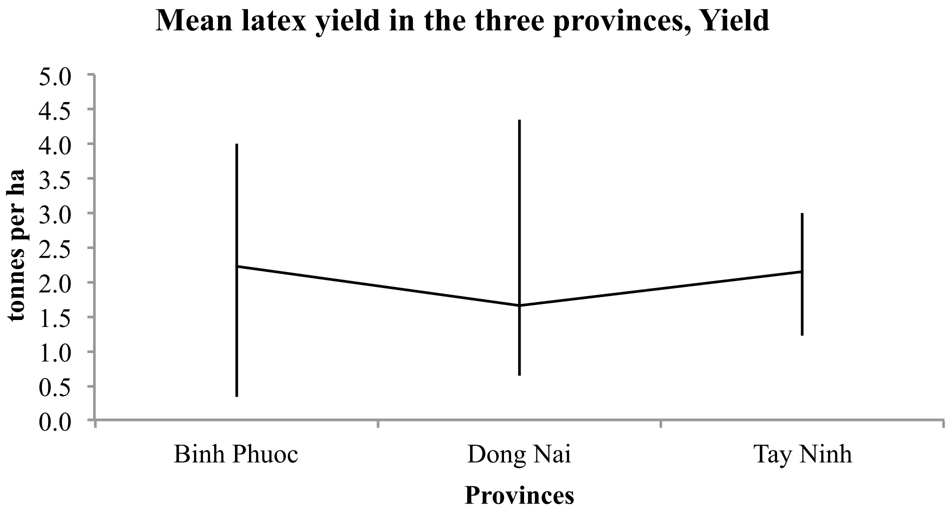

Figure 6.1: Heterogeneity of farm-level latex yield by province, 2013
The vertical lines represent the range of observations (minimum-maximum).
Source: Estimates using the survey data

There is a high variability of *yield* in Binh Phuoc and Dong Nai, but only a small variability in Tay Ninh (Figure 6.1). Although Tay Ninh is considered drier than Binh Phuoc and Dong Nai, its variability in *yield* is lowest when considering the farm level data. This results differs from that found with the secondary data (Figure 5.9).

Mean latex yield in Vietnam was ranked fifth in the world, with 1.65 tonnes/ha and a total production of 602 000 tonnes in 2012 (Nugawela, 2009). Based on the non-normality of latex yield in the study area, median latex yield of 2.0 tonnes per ha is higher the comparative yield of 1.65 tonnes/ha of the country according to the Wilcoxon signed-rank test ($p < 0.01$) (Table 6.1).

Latex yield depends on factors such as the genetic potential of clones, edaphic and topographic suitability, age of rubber trees, stand density[49], length of immature period, the share of tapped area, rotation length, tapping technologies, and the number of tapping days per annum (Diaby et al., 2011; Priyadarshan, 2003; Purnamasari et al., 2002; Viswanathan, 2008; Wibawa et al., 1997; Wijesuriya & Dissanayake, 2009). Latex yield is also directly affected by key factors such as diseases, animal-caused damage, the ability of tappers using correct tapping techniques (tapping slope/depth/length/height as well as usage of cup, wire, spout, placement and guidelines), tapping time, tapping schedules and latex storage tools (Nugawela, 2008a, 2008b, 2009; Priyadarshan, 2003;

[49] Stand is the number of rubber trees per ha.

Wijesuriya & Dissanayake, 2009; Wijesuriya et al., 2007; Wijesuriya et al., 2011; Wijesuriya & Thattil, 2005).

Latex yield and quality also depend partly on crop management decisions and climate variables. However, crop management decisions are also influenced by risks arising from unpredictable climate changes and latex price fluctuations (Purnamasari et al., 2002; RRII, 2010), and they are linked with climate and weather patterns during the plant growth processes (Kurukulasuriya & Rosenthal, 2003).

The majority of rubber growers do not get the maximum benefit from their plantations, due to latex yield being lower than its potential (Nugawela, 2009). In Sri Lanka, with technological support rubber farmers could achieve an optimal yield level of about three tonnes latex per ha per annum (Nugawela, 2009). Mean latex yield in the sample varies from 0.33 to 4.33 tonnes/ha (Appendix 1). Therefore, efforts made to improve latex yield remain a necessity. Next sections use quantitative methods to analyse factors affecting latex yield at the farm level.

6.3 Institutional Factors

6.3.1 Access to Markets

Access to markets is considered an important component of the vulnerability indicator. It plays a crucial role in agricultural development, and it enables countries to moderate negative climate impacts on crops (Reilly et al., 1994). Good access to markets is essential in modern agricultural systems (Dung, 2007). It can enhance physical capital (Viswanathan, 2008) and potential adaptation at the farm level. Farmers with better access to both input and output markets have more chances to implement adaptive measures. For example, the adoption of new technologies may be not preferred in regions with poor access to markets (Kurukulasuriya & Rosenthal, 2003). Input markets allow farmers to acquire what they need for their farming activities. Output markets provide farmers with positive incentives to produce income, and income in turn improves their ability to respond to climate change (Barlow & Muharminto, 1982; Charles & Rashid, 2007; Dung, 2007; Kurukulasuriya & Rosenthal, 2003; Maddison, 2007; Mano et al., 2003; Nugawela, 2008b; Viswanathan, 2008; Wijesuriya et al., 2007). Marketing channels with many intermediaries tend to increase transaction costs and create large gaps between prices rubber farmers receive and prices paid by the final buyers (Barlow & Muharminto, 1982). In the case of rice farming in the Mekong Delta (Vietnam), convenient accessibility and usefulness of local services (including market, agricultural extension, credit, irrigation, education and health care) contribute positively to adaptation strategies of rice farming sectors (Le et al., 2014a).

The main outputs from a rubber plantation consist of liquid latex, coagulated latex and collected scrap[50]. About 91.4 per cent of the farmer households in the sample sold liquid latex as a main output (Appendix 1). The product types farmers sell will depend on economic efficiency, storage ability for each type (Wijesuriya et al., 2007), rubber market demand and institutional context (Viswanathan, 2008).

A rubber farmer may sell latex products at their plantations or at local collecting stores. About 63.6 per cent of the farm households sold their latex products at local collecting stores (Appendix 1). This might affect farmer households' profitability. For example, prices received by farmers can be highly distorted because DRC in latex is measured at the points of sale and can be manipulated by local traders (Viswanathan, 2008). About 91 per cent of the farm households chose local markets to buy their agricultural inputs (Appendix 1), while most of the farmers in the sample assessed the supply of agricultural inputs at medium and good levels (Section 8.2.4). Purchasing places can affect farmer households' cultivation costs and agricultural input use (Dung, 2007).

Table 6.2: Summary statistics of yield against clone sources

No.	Description	Overall	State nurseries	Private nurseries	Self-preparation
1	Median latex yield (tonnes/ha)	2.0	1.5	2.0	1.7
2	Clone sources				
	Binh Phuoc (%)			*76.67*	
	Dong Nai (%)			*68.57*	
	Tay Ninh (%)			*89.29*	
3	Clones obtained from (%)		12.93	79.35	7.72
4	Skewness and Kurtosis test for normality of yield	8.21* *(N=405)*			
5	Kruskal-Wallis equality-of-populations' rank test of median yield	12.16**			
	Rank sum		7541 *(N=49)*	66,939 *(N=318)*	5720 *(N=33)*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

[50] Rubber latex is mixed with impure materials or is fallen underground is called "scrap", so scrap needs to be collected separately to solve before processing.

This section tests whether latex yield of rubber farm households is statistically different across the three clone sources.

Better access to good crop varieties is an important component of modern agricultural systems (Dung, 2007). In Table 6.2, about 79.4 per cent of the farm households bought rubber clones from private nurseries and about 7.7 per cent of them used self-prepared clones. Surprisingly, there is evidence that the farm households who use clones from state nurseries have a lower yield than other farm households. Table 6.2 indicates that *yield* is not normally distributed ($p < 0.05$). The median yield of clones from state nurseries is 1.5 tonnes rubber latex per ha, whereas the group from private nurseries has a median of 2.0 tonnes per ha and the self-preparation group has 1.7 tonnes per ha. The Kruskal-Wallis test tests for three independent-samples' equality of populations' rank of median yield. Statistical differences are found in median yields across the three clone sources. This means the null hypothesis can be rejected ($p < 0.01$). Mottaleb et al. (2015) also found important roles of local seed dealers in technological adoption for rice farming in Bangladesh.

Most farm households in the sample in Binh Phuoc (76.7 per cent) and Tay Ninh (89.3 per cent) used clones sourced from private nurseries, while only 68.6 per cent of the farm households in Dong Nai used this source. This difference of clone sources may explain some of the difference in latex yields across the three province (Tables 6.1).

Rubber clones to replace old trees can be purchased from official or unofficial sources. The quality of clones bought from other farmers is usually low, since some clones are not pure and their origins and names are unclear (Dung, 2007). By contrast, clones from research centres and experimental rubber plantations are generally uniform on a provincial or regional basis. Rubber farmers may not receive appropriate information on the cultivation of unofficial clones, especially basic information on fertiliser application and disease problems. This issue is important for poor farmers after long periods of the immature plant stage, since they may get into debt due to poor harvests (Dung, 2007).

According to Purnamasari et al. (2002) and Nugawela (2009), the low adoption of clonal technology may be due to lack of investment capital and lack of application knowledge. The choice of rubber clones requires an understanding of plant functions not available to most rubber farmers (Diaby et al., 2011; Venkatachalam et al., 2013) and requires technical assistance. Meanwhile, it is not easy to conclude in advance that a certain rubber clone is definitely best in a given agro-environment (Wibawa et al., 1997).

About 85.6 per cent of the farmers said agricultural input costs had increased (Appendix 1). According to Dung (2007), a variation in agricultural input costs over time can impact on farmers' decisions on agricultural input use and their family income. Herbicides, for example, are among the necessary components of weed control. Increased labour wages tend to lower the profitability of hand weeding, and the availability of herbicides encourages their use. Crop yield may be negatively influenced when there is an increase in prices of agricultural inputs, which leads to a reduction in the amount of inputs used, and thus a reduction in crop yield. Barlow and Muharminto (1982) revealed that Indonesian rubber farmers used cheap agrochemicals to coagulate liquid latex rather than use the recommended coagulant formic acid. This action decreased the quality of liquid latex severely. This results in a lack of trust of buyers against sellers, which badly affects the development of the local rubber market. High costs of labour and agricultural inputs constrain the ability of rubber farmers to invest in the best technologies, particularly when they are unaware of the long-term effects of their investments (Nugawela, 2009).

High prices of crop outputs have a significantly positive impact on farmers' decisions on adaptation to climate change (Mendelsohn & Seo, 2007). Low latex prices for a long period constrain the viability and sustainability of rubber cultivation, and the adoption of cultivation practices by small-scale rubber farmers (Wijesuriya et al., 2007). An increase in output prices does not stimulate significant increases in crop yield in the short run, but it will increase farmers' demand for agricultural inputs, and thus will result in higher crop yield.

About 56.6 per cent of the farmers in the sample believe that latex prices will continue to make rubber production profitable and that marketing arrangements are effective (Appendix 1). Natural rubber is still in high demand all over the world due to its unique properties, but its price is beyond the growers' control (Bell, 1986; Nugawela, 2009; Wijesuriya et al., 2007). Good trading conditions from 2003 to the end of 2008, for instance, put Sri Lankan rubber farmers in a comfortable position of profitability. This encouraged an increase in latex yield in the country. The export exchange earnings depended mainly on the international demand of tyres and auto components[51], so any fluctuation in this market or an increase in production cost can cause adverse impacts on the rubber sector (Nugawela, 2009; Wijesuriya & Herath, 2009). If latex prices are low or market arrangements are not effective, family income from rubber cultivation can be negatively affected (Viswanathan, 2008).

[51] Synthetic rubber has never surpassed the quality of natural rubber in terms of elasticity, resilience and high temperature resistance (Venkatachalam et al., 2013), so natural rubber remains in use in tyre production and other auto component manufacture.

6.3.2 Rural Credit

According to McElwee (2010), capital mobilisation is a burden on poor farm households, because they can not afford their loans if their crops fail. Access to credit is important to overcome financial constraints. For example, the adoption of new technologies may be constrained in regions with poor access to credit (Kurukulasuriya & Rosenthal, 2003). In rural areas in Vietnam, farmers may obtain loans from official sources: provincial level (head offices), local level (branches) and/or unofficial sources: rural usury (individuals) (Kirk & Tuan, 2009). In Appendix 1, about 61.6 per cent of the farm households in the sample had access to credit. Only 1.2 per cent of them said the source was from rural usury. Where farmers get loans can depend on their social relationships, previous records, expected amounts and payment ability. Rural usury users pay high interest rates. They thus can be exposed to high risks, especially in severe events such as natural disasters and poor harvests.

About 60 per cent of the farmers liked receiving prepayment from local traders and paying them back in rubber latex later (Appendix 1). This is a form of capital mobilisation. Through verbal agreements from both sides, local traders could prepay money to farm households to reinvest for coming crops. Poor farm households using this arrangement sometimes earned only half of the selling prices obtained by better-off households, resulting in increased vulnerability (McElwee, 2010). However, local traders were reluctant to offer farmers prepayment for crops, because they could not guarantee that the farmers would give them rubber latex instead of selling it to other local traders (Kurukulasuriya & Rosenthal, 2003). Similar practices occur in the study area.

6.3.3 Social Commitment

About 53 per cent of the farmers in the sample answered they did not participate in political organisations, socio-political organisations or occupational associations. About 57 per cent of the farmers participated in rubber farmer groups (Appendix 1). Household heads joining in such social commitments may have more opportunities to gain knowledge and access essential resources that may supplement their human and natural capital (Viswanathan, 2008). However, non-farm activities and social commitments affect farmers' fractional time allocation to agricultural activities (Rodrigo et al., 2009; Wibawa et al., 1997).

About 82 per cent of the farmers have frequent contact with brokers, latex processing and rubber product manufactories (Appendix 1). This frequent contact may involve purchasing activities, investment cooperation or market information exchange. These actions help improve farmers' business power in the markets. Insufficient awareness of the benefits of participation in these groups may cause a low involvement in social commitments. This could hinder development of local industry (Wijesuriya et al., 2007).

6.3.4 Security of Tenure

In Appendix 1, about 83 per cent of the farm households had certificates of land-use rights that gave them security of tenure and other related asset rights (e.g. houses and plant on premises). Security of tenure in the long-term, along with liberalisation of prices in input and output markets, stimulates farmers to invest more in agricultural activities. Farmers now pay land tax based on the assessed value of their land, as written on their land-use right certificates (Dung, 2007). Farmers who obtain security of tenure tend to have a higher propensity to adopt adaptive measures (Charles & Rashid, 2007).

6.3.5 Climate and Weather Forecast Information

In Appendix 1, about 88.3 per cent of the farmer households had access to climate and weather forecast information. Their main source was television (80.5 per cent), radio (15.6 per cent) and newspapers (14.7 per cent), but extension services covered only 9.3 per cent of the farm households in the area (Figure 6.2).

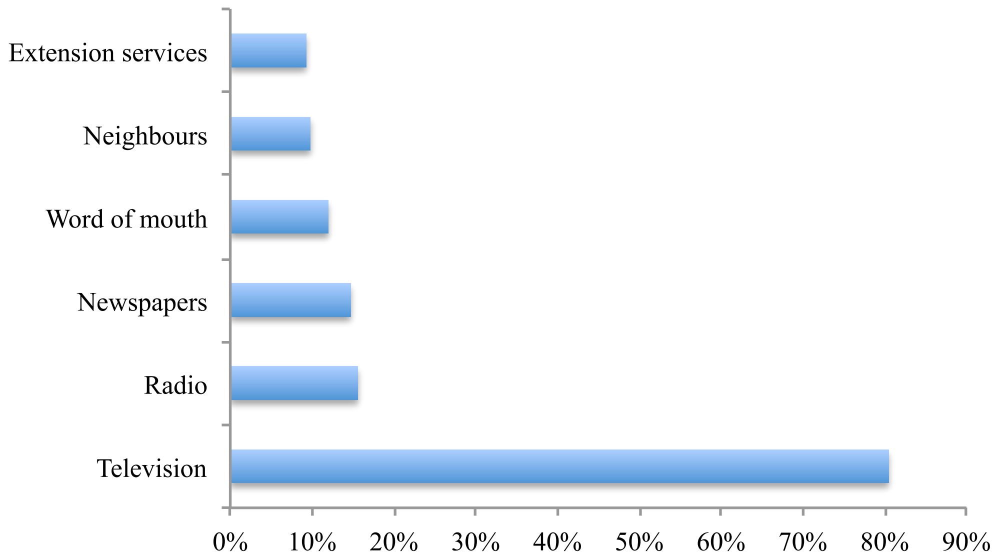

Figure 6.2: Main sources of climate and weather forecast information in the study area

Source: Estimates using the survey data

Access to climate and weather forecast information, both in the short-term and the long-term, is very important to farmers, especially in extreme weather events. Information concerning climate and weather forecasts in agriculture are important factors affecting adoption of adaptive measures. Availability of such information helps farmers make comparative decisions among alternative adaptive measures. Farmers who can obtain this information and apply it in a timely manner will be able to respond best to climate change. This means that timely dissemination of information is important (Baethgen et al., 2003; Charles & Rashid, 2007; Jones, 2003; Kandlikar & Risbey, 2000;

Kurukulasuriya & Rosenthal, 2003; Lal et al., 2001; Lasco et al., 2011; Maddison, 2007; Nugawela, 2008b). Timely dissemination of the forecast information to farmers could enhance their ability in coping with climate change and variability. Timely access helps farmer households' preparation in coping with adverse effects of climate and weather on their agricultural activities.

Reliable data of climate change and variability are not commonly available in some countries, but lack of such data is not the only problem. The real problem is a lack of application of prevailing climate and weather forecast information, which is due to poor value of information or ungraspable information. Farmers' ability to analyse such information allows them to adjust their agricultural activities in advance (Kurukulasuriya & Rosenthal, 2003).

6.3.6 Agricultural Extension Activities

Access to extension services may be direct or indirect from numerous sources. About 52.6 per cent of the farm households had access to extension services (Appendix 1). The farmers often received agricultural recommendations from several sources, with television being the main source (36.3 per cent), followed by learning by doing with 28.8 per cent (Figure 6.3). Learning-by-doing was also a main economic aspect of technology use by Indonesian small-scale rubber farmers (Barlow, 1997).

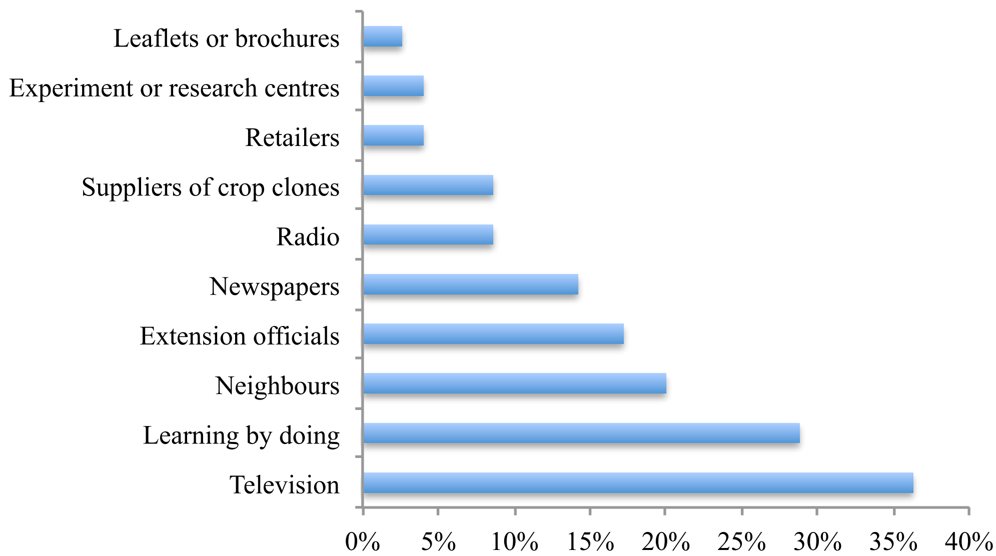

Figure 6.3: Main sources of agricultural recommendations in the study area

Source: Estimates using the survey data

Besides the MARD's the National Agriculture Extension Centre (NAEC) and centres of agricultural extension at the provincial level, there are agricultural extension stations at the district level and farmer clubs at the village level. At the grassroot level, there are about two agricultural extension officers who work permanently in each village and there is an agricultural extension collaborator who works semi-permanently in each sub-village unit. All these organisations are set up as a vertical system to perform agricultural development activities in the whole country. Besides extension services of state organisations in Vietnam, there are non-state organisations that also can supply these services. However, some services (related to plant variety, fertiliser, herbicide and pesticide) have been strictly controlled by specialised inspection agencies.

Some of the main objectives of extension services are to research, apply and support agricultural development, especially in rural areas. Extension contributes to the Government's target of industrial development accompanied with industrialisation and modernisation of rural agriculture. Current activities aim at three main aspects: (i) providing agricultural information, (ii) training for farmers and (iii) establishing models of good agricultural practices for subsequent use by farmers. Extension services aim to support farmers, but they appear not to be effective enough to attract farmers' attention (Long et al., 2013). Total expenses in 2012 for extension activities in Vietnam was about 2.5 USD per farm household, while this number was about 50–80 USD in Thailand, Malaysia, Indonesia and the Philippines (MARD, 2013). Binh Phuoc, Dong Nai and Tay Ninh usually hold training programs for farmers on planting, nursing rubber trees and tapping for latex. However, such programs usually focus on poverty reduction. Rationing of extension services may be caused by the institutional status or farmers' insufficient awareness of such services. In Vietnam, the NAEC is responsible for making technical recommendations and technological transfer to farmers. However, this agency rarely provides market information that is also important to farmers (Dung, 2007).

Extension services in developing countries have played a primary role in improvement of agricultural productivity and adaptation to climate change (Adesina & Chianu, 2002; Kurukulasuriya & Rosenthal, 2003). The supply of extension services is measured by the number of extension organisations per region or membership of extension organisations (Kurukulasuriya & Rosenthal, 2003). According to Charles and Rashid (2007), there is a strong correlation between the supply of extension services and improvement of farmers' awareness and knowledge about agronomic practices, as well as the supply of extension services and the adoption rates of agronomic practices. The farmers who have frequent contact with extension services will have better chances of being aware of climate change and crop management practices[52], so that they can adapt to climate change. It is unlikely that farmers would have received necessary information about adaptive measures without widely available extension programs.

[52] Crop management practices may consist of altering applications of nutrients, agrochemicals as well as changing cultivation and harvest schedules (Lal et al., 2001).

However, farmers' farm size and education levels may have a significant influence on the probability of receiving extension services. Poor enthusiasm of extension officials and organisational failures can be reasons for poor agricultural productivity (Kurukulasuriya & Rosenthal, 2003). Lack of local extension officials and lack of necessary facilities for these officials would constrain the performance of rubber cultivation (Nugawela, 2009).

6.3.7 Education and Training Activities

In Appendix 1, about 92.8 per cent of the farmer households in the sample were trained in planting and nursing rubber trees (representing 77.9 per cent of the trained farmers), tapping for latex (65.6 per cent), protecting against rubber plant diseases (55.6 per cent), applying fertiliser (50.7 per cent) and processing rubber latex (8.4 per cent) (Figure 6.4). There is no significant correlation between latex yields of farm households trained and farm households untrained in the sample.

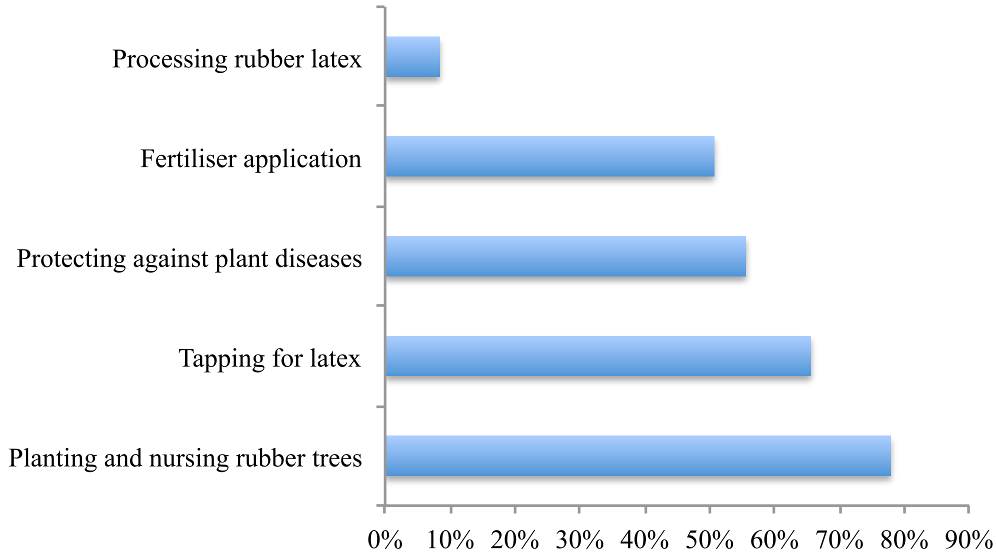

Figure 6.4: Proportion of training activities in the study area

Source: Estimates using the survey data

Training activities support rubber farmers' successful application during immature and mature stages of rubber plantations. Findings from Dung (2007), for example, indicated that Vietnamese rice farmers joining in training activities for pesticide application were expected to take more reasonable decisions about the amount and timing of pesticide application compared with farmers who did not join in such activities. Farmers who engaged in training could achieve higher profitability than other farmers.

Although Southeast Vietnam had the highest percentage (5.25 per cent) of skilled workers (from primary technical levels upwards) in the country in 2011, more than 97 per cent of agricultural, forestry and fishery workers had not been trained and had no professional certificates (GSO, 2012). Meanwhile, "the redundant agricultural employees are mainly unskilled workers" (GSO, 2012, p. 105). Lack of training would constrain the livelihoods of farmers as well as socio-economic development and sustainability of the region in general (Wijesuriya et al., 2007). Insufficient awareness of tapping and training programs of tapping skills affect the number of skilled tappers (Wijesuriya & Dissanayake, 2009).

6.3.8 State Subsidies

A range of countries such as Vietnam, China, Cambodia, Laos PRD, Sri Lanka and even Australia, have attempted to develop replanting and new planting in NTRAs (Bell, 1986; Fox & Castella, 2013; Wijesuriya et al., 2011). Some subsidy schemes from governments have contributed to rubber cultivation development, especially standard growth in immature rubber plantations (Wijesuriya et al., 2007). Agricultural subsidies from governments may consist of agricultural inputs (young plants, planting materials, agrochemicals), in-kind (irrigation technology) and cash. For example, many Indonesian rubber growers were supported by state-sponsored schemes, which provided low-cost loans with long payback periods (12 to 15 years) at interest rates of 10 to 15 per cent (Purnamasari et al., 2002) and promoted replanting with high-yield clone materials (Barlow & Muharminto, 1982). In Appendix 1, only 19.5 per cent of the farmer households received local government's agricultural subsidies.

6.4 Socio-Economic Conditions

6.4.1 Family Income

About 87.2 per cent of the farm households in this study had main income[53] from agricultural activities. Net profit[54] per rubber ha in the surveyed sample in 2013 was just over 44 million VND, equivalent to 2200 USD (Appendix 1). Ideally, assessment of net profit would involve the same rubber clones, so that only one source of net profit variation is assessed. Nevertheless, the analysis here only focuses on latex yield variation of sampled rubber farm households.

This section tests whether net profit per ha of rubber farm households is statistically different across the three provinces.

[53] On-farm family income equals gross return of harvest minus all related costs, excepting family labour wages (Dung, 2007).

[54] Rubber farmers' annual net profit from per ha is simple estimated by multiplying average latex yield by the average farm-gate price and minus all related production costs in the current year, excepting family labour wage.

Table 6.3: Summary statistics of net profit in the three provinces

No.	Description	Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Median net profit (million VND)	43.0	50.0	30.0	50.0
3	Shapiro-Wilk W test for normal data of net profit	6.77** *(N=409)*			
4	Kruskal-Wallis equality-of-populations' rank test of median net profit	77.68**			
	Rank sum		32,782 *(N=146)*	15,794 *(N=123)*	35,270 *(N=140)*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

As shown in Table 6.3, *net profit* is not normally distributed ($p < 0.01$) according to the Shapiro-Wilk W test. Statistical differences are found in median *net profit* across the three provinces ($p < 0.01$) according to the Kruskal-Wallis test. Farmers in Tay Ninh and Binh Phuoc had the highest net profit, followed by Dong Nai. These rankings are consistent compared to their rankings of latex yields in Table 6.1. High latex yield has a statistically strong correlation to net profit at the farm level ($p < 0.01$) (Appendix 1). Apart from fluctuations in latex prices which are unobserved in this study, increases in yield are associated with increases in net profit. Such yield-profit growth is a good signal in the local rubber industry.

Incomes from crop cultivation and other activities contribute to improve farmer households' purchasing power of agricultural inputs and technology (Dung, 2007; Kurukulasuriya & Rosenthal, 2003; Rodrigo et al., 2009), but profitability from crop cultivation would contribute little to the income of farm households with poor endowments of farm size and education. Such a situation would be even more serious for farm households that obtain their entire income from crop cultivation and have many dependent members in the family (Dung, 2007). This study does not find any correlation of net profit with farm size, education and number of dependent members. Lasco et al. (2011) indicate poor farmer households' adaptive capacity, therefore, is low in extreme weather events.

Rubber farmer households in the study area may bring up poultry (e.g. chickens, ducks) and/or bees on their plantations for income improvement. Only 16 per cent of the farm households had the combination of poultry and/or bees with rubber cultivation (Appendix 1).

A rubber farm household's profit depends on latex production and latex prices as well as the costs involved in producing latex. These factors also depend mostly on management decisions of farmers (Dung, 2007; Priyadarshan, 2003; Purnamasari et al., 2002; Viswanathan, 2008). Latex prices at the farm-gate are not uniform for rubber farm households, they depend on the power of local traders, latex quality and latex supply in the market. Rubber farmers who cannot coagulate latex, who need cash for daily expenditures or who sell only a small quantity of latex, generally receive lower prices from local traders. To achieve higher profits from rubber cultivation and efficiency from agricultural input use, rubber farmers also need to operate at the economic optimum rather than at the technical optimum.

An increase in family income is partly due to increased yields or reduction in production costs, but also a key factor behind an increase in family income is greater employment of family labour in agricultural activities. Accompanying fluctuations in rubber markets, rubber farmers face difficulties in improving income and choosing adaptive measures. They need to save costs of labour, capital, agrochemicals and clones through simplifying technical requirements. As a consequence, latex production and yield tend to be below desirable levels.

In the sample, 28.4 per cent of the farmers had main occupations other than farming, and about 68.2 per cent of the farmers had other non-farm income (Appendix 1). Agricultural households may be more vulnerable than non-agricultural ones to severe weather events. In other words, non-agricultural households may be more resilient than agricultural ones. Vulnerability of farm households would be more serious for those that obtain their entire income from crop cultivation (Dung, 2007). Therefore, family income from non-farm activities is an important component of financial capital (Viswanathan, 2008). Household heads who earn non-farm income may reduce their households' dependence on natural conditions (Wijesuriya & Dissanayake, 2009). If small-scale farmers diversify their farming and non-farm activities, their livelihoods are strengthened (Viswanathan, 2008). Diversification of income sources and employment opportunities are important adaptation strategies for farm households (Downing et al., 1997). The ability to obtain non-farm income is influenced by factors such as climatic conditions, availability of alternative employment and future employment opportunities (Kurukulasuriya & Rosenthal, 2003). Adger et al. (2002) indicate that incomes invested in human or physical capital could enhance agricultural productivity. However, incomes could also be sometimes used in unproductive ways, even with no direct relation to crops (Kurukulasuriya & Rosenthal, 2003).

6.4.2 Rubber Land Size

Large farms tend to be more efficient (Mesike et al., 2009; Wijesuriya et al., 2011) and may provide economies of scale and affect total farm income (Dung, 2007; Wijesuriya & Dissanayake, 2009) and adaptation opportunities (Adesina & Chianu, 2002). For instance, between 1967 and 1997 small-scale farmers in Indonesia improved latex yield from 462 kg to 597 kg/ha. This was low compared to estates that improved latex yield from 606 kg to 1015 kg/ha over the same period (Purnamasari et al., 2002).

In Appendix 1, based on the *Spearman* correlation test, there is a statistically significant correlation between rubber land size and mean latex yield from the survey data ($\rho = 0.2$, $p < 0.01$). A statistically significant correlation is also found between rubber land size and net profit from this dataset ($\rho = 0.2$, $p < 0.01$).

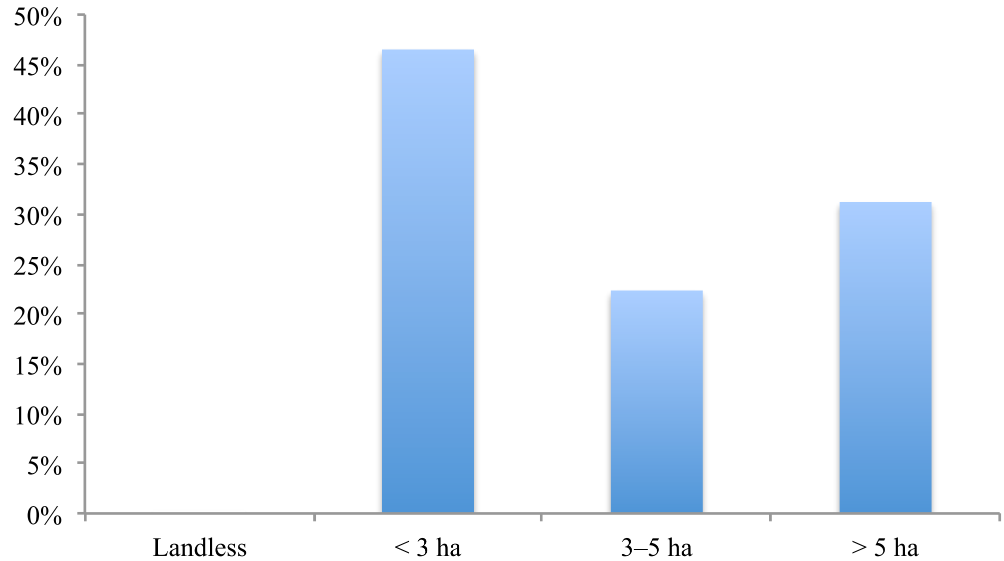

Figure 6.5: Rubber land size of farm households in the study area
Source: Estimates using the survey data

Regarding the area of rubber plots, about 46.5 per cent of the farm households have < 3 ha, and 22.3 per cent of them have between 3 and 5 ha. The rest of them have > 5 ha (31.2 per cent), but no farm households are landless (Figure 6.5).

In Appendix 1, rubber farm households in the sample used most of their land capacity (total land area) for growing rubber trees (rubber farm size). The mean farm size among the households was 4.7 ha.

Rubber farmers can own more than one plot of rubber plantation. In the survey area about 45.8 per cent of the farmer households owned 2 plots or more of rubber plantations (Appendix 1). This scattering of owned land is an important component of financial capital, but can affect the efficiency of scale economies. Land fragmentation is also a drawback for agricultural commercialisation (Kirk

& Tuan, 2009). Growing a number of different crops in the same plot or in different plots reduces the risk of complete crop failure, because different crops are affected differently by climate change and variability (Charles & Rashid, 2007).

6.4.3 Farm Infrastructure

The respondents were asked to estimate distances to four closest important places related to agricultural activities, such as local markets, urban markets, commune roads and administration centres. The mean distance was 13.3 km (Appendix 1). Better access to roads and markets is an important component in modern agricultural systems (Dung, 2007) and is one of the factors affecting adaptive capacity (Adesina & Chianu, 2002). Local markets, urban markets, commune roads and administration centres are places where farmers can purchase inputs and outputs as well as getting useful information for agricultural activities. Rubber farmers in scattered-remote areas have difficulty applying advanced technologies, since such areas usually experience higher transaction costs. The poor can get lower levels of crop yield and prices due to inadequate access to roads and markets (Yu et al., 2013).

This section tests whether access of rubber farm households to roads, markets and administration centres is statistically different across the three provinces.

Table 6.4: Summary statistics of distance to markets, roads and administration centres

No.	Description	Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Median distance (km)	11.75	11.00	16.13	10.75
2	Shapiro-Wilk W test for normal data of distance	8.77** *(N=423)*			
3	Kruskal-Wallis equality-of-populations' rank test of median distance	36.17**			
	Rank sum		28,693 *(N=147)*	35,786 *(N=136)*	25,197 *(N=140)*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Table 6.4 shows that variable *distance* is not normally distributed ($p < 0.01$) according to the Shapiro-Wilk W test. Statistical differences are found in three independent-samples equality of populations' rank of median *distance* across the three provinces ($p < 0.01$) according to the Kruskal-Wallis test. Farmers in Dong Nai had a greater travel distance to the four important places compared to farmers in Binh Phuoc and Tay Ninh. The rapid industrialisation rate in Dong Nai has replaced agricultural land and remaining plantations are more distant from town centres.

Good access to roads and markets may increase agricultural productivity in several ways. It decreases purchasing costs, increases availability of agricultural inputs, and increases opportunities for marketing (Yu et al., 2013). Distance to the market for pesticides, for example, influences the farm-gate prices among farm households (Dung, 2007). Investment in rural infrastructure can indirectly affect crop yield growth as well as labour productivity. According to Barlow and Muharminto (1982), upgrading roads and infrastructure is expected to decrease marketing costs and increase profitability. In Vietnam, the government is responsible for construction and maintenance of infrastructure.

The main types of waste treatment, as identified in Vietnamese statistics, include whether garbage is collected, transported to a common dump, buried or burned, thrown anywhere and treated in other ways. In the sample, 50.5 per cent of the farmer households buried or burned garbage, 18.0 per cent of them collected garbage, 26.0 per cent treated it in other ways, 3.8 per cent transported it to a common dump and 1.6 per cent garbage threw anywhere (Figure 6.6). This information shows sanitary conditions and quality of the living environment at rubber plantations.

Appropriate drainage methods could decrease water runoff and improve water uptake (Kurukulasuriya & Rosenthal, 2003). Better drainage helps rubber tree growth and latex yield (Priyadarshan, 2003). The main sewage drainage types include gutters with covers, gutters without covers, other types of sewage drainage system and no sewage drainage system. Thirty per cent used gutters with or without covers, 19.8 per cent used other types of sewage drainage system and 50.2 per cent had no sewage drainage system (Figure 6.6). These above results are quite consistent with statistics cited in Chapter 3.

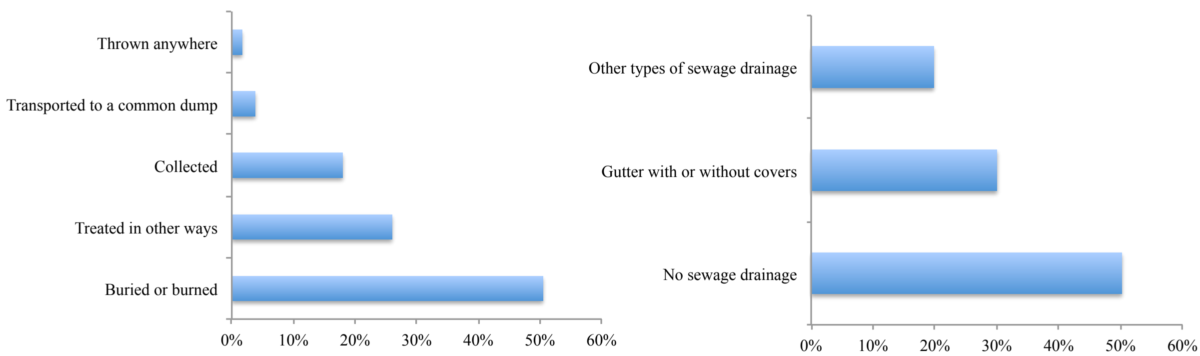

Figure 6.6: Types of waste treatment and sewage drainage in the study area

Source: Estimates using the survey data

Better access to irrigation systems is an important component in modern agricultural systems (Dung, 2007). It has played a crucial role in agricultural production and adaptation to climatic conditions (Mainuddin & Kirby, 2009; Perera & Seneviratne, 2009). Access to irrigation facilities may be from groundwater (drilled wells) and/or surface water (ponds or dug wells). About 54.5 per cent of the households in the study had access to irrigation facilities. Of these, 73.7 per cent used underground water as their main water source for agricultural production. About 90 per cent of farmers interviewed in Tay Ninh had convenient access to irrigation facilities, whereas this proportion in Binh Phuoc was lower (27 per cent) compared to Dong Nai (47 per cent) (Table 6.6). There is a statistically significant difference in percentages of farmers with access to irrigation across the three provinces according to the Chi-squared test ($p < 0.01$). This can explain why no farmers in Binh Phuoc in the survey used water-saving irrigation technologies (Table 7.2). However, 21 per cent of the farmers in the sample considered the local supply of irrigation technologies as not good that can impact on farmer households' decisions on the adoption of irrigation technologies (Appendix 1).

Irrigation and water availability have the potential to improve agricultural productivity through supplementing soil moisture and lengthening growth periods (Adesina & Chianu, 2002; Baethgen et al., 2003; Kurukulasuriya & Mendelsohn, 2007a). Irrigation facilities support rubber tree growth and development, but available groundwater and surface water are limited even in wet zones due, in part to climate change (Rodrigo et al., 2009). Expanded irrigation using groundwater extraction could also result in groundwater depletion and could increase the cost of pumping that poor farmers are unlikely to afford (Alauddin & Sarker, 2014). Decreased precipitation needs to be offset by further aquifer exploitation. This places additional burdens on surface and underground water resources, especially as water demand for industrial and municipal zones is also increasing (Kurukulasuriya & Rosenthal, 2003). Therefore, expanded irrigation using groundwater extraction to adapt to climate change may be unsustainable in the end (Alauddin & Sarker, 2014).

The availability of electricity can boost agricultural productivity through machinery usage (Yu et al., 2013). Access to electricity in general may enrich farmer households' natural capital and affect the running of irrigation systems. Farm households with better access to electricity have a better chance of using adaptive measures (Charles & Rashid, 2007). Access to electricity in rural agricultural areas may be from the national electricity grid, small hydropower stations, solar batteries and other types of batteries. Only 26 per cent of the farmer households in the sample used electricity at their plantations. This can explain the small number of rubber farmer households (9.6 per cent) using water-saving irrigation technologies in the study area (Appendix 1), because they require electricity.

6.5 Agro-Environment

Farm households face different conditions for cultivation, in terms of soil quality, topography and irrigation system. Soil quality is a valuable indicator for capturing these differences. Types and texture of soil affect rubber tree growth and latex yield (Priyadarshan, 2003; Senevirathna et al., 2010; Wijesuriya & Thattil, 2005). It is said that "rubber experiences an initial growth phase varying generally from 5 to 7 years, depending on climate, soil conditions and management" (Venkatachalam et al., 2013, p. 1301). Furthermore, current growth influences future growth of rubber trees.

6.5.1 Soil Types

The types of soil in the three provinces are mainly *ferralsols* (red basalt), *acrisols*, *andosols*, *fluvisols*, *luvisols*, *gleysols* and *leptosols* (FAO, undated). According to Wijesuriya et al. (2007), unsuitable soil types can lengthen the immature period and cause substandard growth in immature rubber plantations.

This section tests whether latex yield of rubber farm households is statistically different across soil types.

In Table 6.5, the farmer households interviewed grew rubber trees on *ferralsols* (34.8 per cent) and *acrisols* (51.5 per cent) making 86.3 per cent of the farmer households. Proportions of these soil types are different across the three provinces according to the Fisher's exact test ($p < 0.01$). About 89 per cent of farmer households in Binh Phuoc grew rubber plants on *ferralsols* and *acrisols*, while this rate was 92 per cent in Dong Nai. About 77 per cent of farmer households in Tay Ninh grew rubber plants on *acrisols* but only 0.7 per cent on *ferralsols*.

Acrisols appears to be compatible with yield improvement of rubber trees, because latex yields in Binh Phuoc and Tay Ninh are the highest, followed by Dong Nai. The farmer households growing rubber trees on *acrisols* have higher yields than other farmer households. The median of the group having *ferralsols* is 1.7 tonnes of latex per ha, the median of the group having *acrisols* is 2.1 tonnes and the median for other soil types is 1.6 tonnes. The hypothesis that medians of yield are the same across the three categories of soil is rejected according to the Kruskal-Wallis equality-of-populations rank test of median yield ($p < 0.01$). This indicates that rubber farmer households in the study area benefit from growing rubber trees on the appropriate soil types.

Table 6.5: Summary statistics of soil types in the three provinces

No.	Description	Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Structure of soil types (%)				
	Ferralsols	34.82	*32.0*	*71.4*	*0.7*
	Acrisols	51.53	*57.1*	*20.7*	*76.8*
	Other soil types	13.65	*10.9*	*7.9*	*22.5*
2	Fisher's exact test for differences in proportions of the apply of soil types (*p*-value)	0.000			
3	Skewness and Kurtosis test for normality of yield	8.21* *(N=405)*			
4	Median yield against soil types (tonnes/ha)				
	Ferralsols	*1.7*			
	Acrisols	*2.1*			
	Other soil types	*1.6*			
5	Kruskal-Wallis equality-of-populations' rank test of median yield	16.89**			
	Rank sum				
	Ferralsols	24,020 *(N=130)*			
	Acrisols	47,688 *(N=215)*			
	Other soil types	8894 *(N=56)*			

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

6.5.2 Land Topography

Land topography in Southeast Vietnam has three main features: hills, slopes and plains. Land topography affects rubber cultivation conditions (e.g. irrigation, tillage, fertiliser application) and the associated land preparation. In Table 6.6, only 6.4 per cent of the farmer households in the sample grew rubber trees on hills. About 43.8 per cent grew rubber plants on gentle slopes and 49.9 per cent on plains. Land topography for growing rubber trees by farmer households in Binh Phuoc and Dong Nai is quite similar, but Tay Ninh differs with 74.3 per cent of farmer households growing rubber trees on plains. Proportions of these topographic types are different across the three provinces according to the Fisher's exact test ($p < 0.01$). These numbers may explain why 90 per cent of farmer households in Tay Ninh had convenient access to irrigation facilities, with lower numbers in Binh Phuoc (27 per cent) and Dong Nai (47 per cent).

Table 6.6: Summary statistics of land topography in the three provinces

No.	Description	Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Types of land topography (%)				
	Hills	6.35	*9.5*	*8.0*	*1.4*
	Gentle slopes	43.76	*53.4*	*53.3*	*24.3*
	Plains	49.88	*37.2*	*38.7*	*74.3*
2	Fisher's exact test for differences in proportions of the apply of topographic types (*p*-value)	0.000			
3	Has convenient access to irrigation (%)	54.52	27.08	47.45	89.93
4	Chi-squared test for differences in proportions of farmers who access irrigation	116.76**			

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Soil erosion due to steep topography is one of the factors affecting adaptation (Adesina & Chianu, 2002). The poor tend to get lower crop yields often because of the steep topography of their land (Yu et al., 2013). In this study statistical differences of latex yield across topographic conditions are not found.

6.6 Demographic Characteristics

6.6.1 Age of household head

The mean age of the farmers interviewed was about 50 years (Appendix 1). Mean age is one of the components of human capital (Viswanathan, 2008) and can be used to explain farmers' decisions on the adoption of agricultural technology (Adesina & Chianu, 2002). This variable also identifies whether the respondent is of working age (Section 3.4.3). An older head tends to be more experienced in farming. In Appendix 1, there are significant positive correlations between age of household head and their years involved in farming across the three provinces from the survey data

($p < 0.01$) according to the *Spearman* correlation. In Table 6.7, there is evidence that younger farmers have other occupations in addition to rubber tree growing. The mean of the group having main occupations other than agriculture was about 45 years old, and the mean of the group having main occupation as agriculture was about 51 years old. The hypothesis that means of the age of household head are the same across the two categories of occupations is rejected according to the two independent samples t-test with equal variances and unequal variances ($p < 0.01$). The younger generations in Sri Lanka also preferred other occupations to rubber tree growing, because tapping work was not considered a reputable occupation or might be often chosen by migrant labour (Wijesuriya et al., 2007).

This section tests whether age of farm household head against occupations is statistically different.

Table 6.7: Summary statistics of age of household head against occupations

No.	Description	Overall	Agriculture	Others
1	Skewness and Kurtosis test for normality of age	5.67 *(N= 424)*		
2	Mean age against occupations (years)	49.53	51.09	45.49
3	Two independent samples t-test with equal variances *diff.* = *mean*(agriculture) – *mean*(others)	4.94** ≥ 0		
4	Two independent samples t-test with unequal variances *diff.* = *mean*(agriculture) – *mean*(others)	5.01** ≥ 0		

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

6.6.2 Gender of household head

Gender is another component of social capital (Adesina & Chianu, 2002; Viswanathan, 2008). Normally a female household head is more likely to take up adaptive measures, because women usually do most farming activities in rural areas, while men usually look for jobs in towns (Charles & Rashid, 2007; Viswanathan, 2008). In Table 6.8, only 30.7 per cent of the farmers interviewed are female. However, the Chi-squared test for relationship between gender and occupations gives no statistically significant result.

Table 6.8: Summary statistics of gender against occupations

No.	Description	Overall	Agriculture	Others
1	Gender of household head (%)			
	Female	30.70	*68.2*	*31.8*
			(N=90)	*(N=42)*
	Male	69.30	*73.2*	*26.8*
			(N=218)	*(N=80)*
2	Chi-squared test for proportions of relationship between gender and occupations	1.11		

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

6.6.3 Ethnic Community and Marital Status

Ethnic community is also a component of human capital (Viswanathan, 2008). Although there are many ethnic communities living in the study area, the majority are Kinh (DS, 2012). In Appendix 1, other ethnic communities present are only 2.3 per cent in the survey, thus comparisons in relation to these communities and Kinh are not included. A person who is married is considered more mature in life and agricultural activities (Wijesuriya et al., 2007). About 96 per cent of the farmers in the sample are married.

6.6.4 Years of Schooling

Years of schooling measure the highest education level obtained by the respondent. According to Arnon (1981), Charles and Rashid (2007) and Wijesuriya et al. (2007), a rubber farmer's education level contributes to efficiency in agricultural production and rubber cultivation. This occurs by enabling farmers to (i) perceive that changes have occurred, (ii) collect, retrieve and analyse useful information, (iii) draw valid conclusions from available information and (iv) act quickly and decisively (Wijesuriya et al., 2011).

This section tests whether education level of household head against labour use is statistically different.

Table 6.9: Summary statistics of education level against labour hiring

No.	Description	Overall	Family labour	Hire labour
1	Skewness and Kurtosis test for normality of education level	4.58 *(N= 426)*		
2	Mean of schooling years (years)	9.69	8.51	10.31
3	Two independent samples *t*-test with equal variances	-4.52**		
	diff. = *mean*(family lab.) – *mean*(hire lab.)	≤ 0		
4	Two independent samples *t*-test with unequal variances	-4.64**		
	diff. = *mean*(family lab.) – *mean*(hire lab.)	≤ 0		

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

In Table 6.9 and Appendix 1, the mean schooling of the farmers interviewed was < 10 years. This corresponds to a level is in the range of upper secondary. There is evidence that farmers with higher years of schooling have a higher probability of hiring labour than others. Hiring labour helps guarantee that a skilled workforce is available by providing a steady source of income during tapping periods. The mean of the group hiring labour was about 10 years of schooling, and mean of the group not hiring labour was about 9 years of schooling. The hypothesis that means of years of schooling of household head are the same across the two categories of labour use is rejected using the two independent samples *t*-test with equal variances and unequal variances ($p < 0.01$). Wijesuriya et al. (2007) also found similar evidence.

This section tests whether education level of household head against occupations is statistically different.

Table 6.10: Summary statistics of education level against occupations

No.	Description	Overall	Agriculture	Others
1	Skewness and Kurtosis test for normality of education level	4.58 *(N= 426)*		
2	Mean of schooling years (years)	9.66	8.42	12.78
3	Two independent samples *t*-test with equal variances	-11.68**		
	diff. = *mean*(agriculture) - *mean*(others)	≤ 0		
4	Two independent samples *t*-test with unequal variances	-10.73**		
	diff. = *mean*(agriculture) - *mean*(others)	≤ 0		

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Using the same tests as above, farmers with higher years of schooling have main occupations other than agriculture ($p < 0.01$) (Table 6.10).

This section tests whether education level of household head against social commitments is statistically different.

Table 6.11: Summary statistics of education level against social commitments

No.	Description	Overall	No commitments	Commitments
1	Skewness and Kurtosis test for normality of education level	4.58 *(N= 426)*		
2	Mean of schooling years (years)	9.66	8.69	10.72
3	Two independent samples *t*-test with equal variances	-5.29**		
	diff. = *mean*(no com.) - *mean*(com.)	≤ 0		
4	Two independent samples *t*-test with unequal variances	-5.25**		
	diff. = *mean*(no com.) - *mean*(com.)	≤ 0		

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Using the same tests as above, farmers with higher years of schooling have a higher probability of participating in social commitments ($p < 0.01$) (Table 6.11).

Insufficient basic education is among the factors constraining farmers from acquiring new skills and technologies, and restricting them from opportunities for higher non-farm income (Dung, 2007; Wijesuriya et al., 2007). According to Dung (2007), farmers learn background skills during their years of schooling, of which reading, writing and arithmetic are particularly important. These skills help farmers to make simple calculations such as fertiliser conversion to nutrient units. Farmers with only primary education level have difficulty in reading technical information in brochures and chemical labels, and/or keeping farm records. Though state efforts are made to train farmers to adopt new technology, it is obviously more difficult for illiterate farmers (Yu et al., 2013). Therefore, the education level of the farm household head is an important factor affecting their decisions on rubber cultivation.

6.6.5 Years Involved in Farming

The mean years involved in farming was < 20 years in the sample (Appendix 1). This variable indicates accumulated experience and influences considerably farmers' perception of and their adaptation to climate change (Perera & Seneviratne, 2009), and may enhance their adaptive capacity (Adesina & Chianu, 2002). According to Charles and Rashid (2007) and Senevirathna et al. (2010), an experienced farmer is likely to better perceive climate change and is likely to have a higher probability of uptake of adaptive measures. An experienced farmer is likely to get more information and knowledge on changes in climatic conditions and crop management practices. They are usually leaders and progressive farmers in rural areas. They thus can perceive and adapt to climate change more easily. These farmers' success can promote appropriate adaptive actions by other farmers who do not have such experience.

Local knowledge from years involved in farming is also important (Figaredo, 2009). Local knowledge refers to locally derived understanding about the environment and agricultural activities that are based on local farmers' experience and practice (Senevirathna et al., 2010). The local knowledge base is identified in terms of rubber trees' performance (growth and yield), crop management practices and knowledge sources relating to rubber cultivation. Although the relationship between local knowledge and scientific knowledge is still controversial in terms of supplements and substitutes, local knowledge has played a vital role in agricultural practices (Senevirathna et al., 2010).

6.6.6 Occupation of household head

The occupation of the household head is presented in Sections 6.4.1, 6.6.1, 6.6.2 and 6.6.4. Occupation also indicates farmers' time allocation to agricultural activities (Rodrigo et al., 2009). Rubber farmers' time availability for farming is limited because of their non-farm activities, so poor maintenance and low growth of rubber trees may occur (Barlow & Muharminto, 1982; Wibawa et al., 1997).

6.6.7 Household Size

The mean household size in the sample was < five members (Appendix 1). The size distribution is presented in Figure 6.7. There are no significant correlations found between latex yield and household size from the survey data.

Large households may have advantages in terms of their supply of workforce, but may have disadvantages in sharing resources among family members (Viswanathan, 2008). Labour unavailability is considered a key input constraint. The expectation is that farm households with more labour are better able to take on various adaptive measures to climate change, compared to those with limited labour (Charles & Rashid, 2007). However, 9 per cent of the farmer households in the sample considered the local supply of hired labour as not good and that could impact on farmer households' decisions on labour use (Appendix 1).

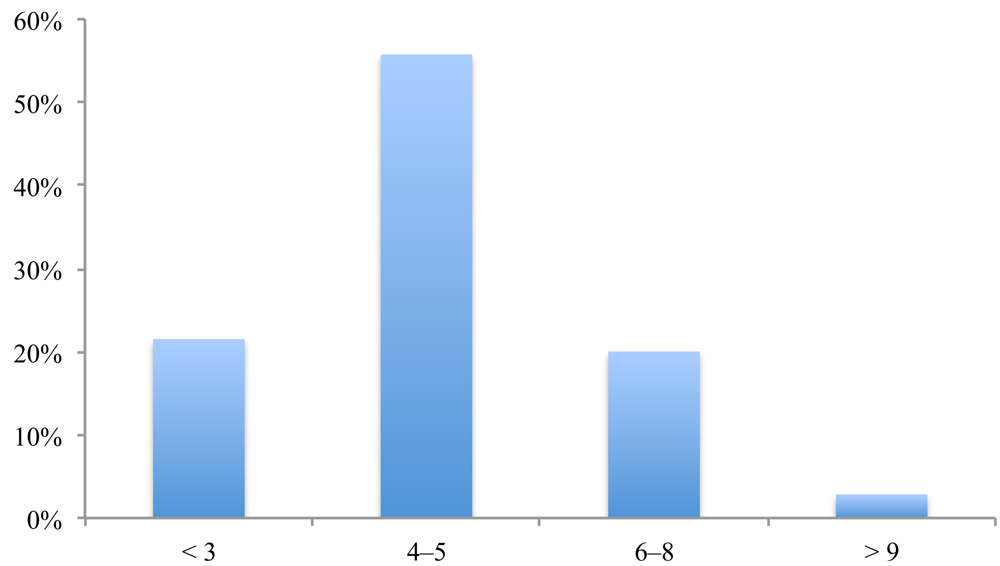

Figure 6.7: Family labour structure for farming activities in the study area

Source: Estimates using the survey data

6.7 Farm Characteristics

6.7.1 Age of Rubber Trees

There is a natural decrease in latex yield per rubber tree after the 9th year of tapping (Purnamasari et al., 2002; Wibawa et al., 1997). The mean age of rubber trees in the survey area was just over 10 years (Appendix 1). About 95 per cent of the farmer households in the sample had rubber plantations in mature stages (mean age of rubber trees > 6), so these farm households could receive income from rubber. This section tests whether age of trees is statistically different across the three fertiliser-application types.

There is evidence from the field survey that the three fertiliser-application levels are different across the median ages of rubber trees. The hypothesis that the three levels of fertiliser application are the same across median ages of rubber trees is rejected based on the Kruskal-Wallis equality-of-populations rank test of median age of trees ($p < 0.01$). About 27 per cent of the farmer households in the sample applied less fertiliser than recommended for trees with the median age of 8. About 29 per cent of the farmer households applied more fertiliser than recommended for trees with the median age of 10 (Table 6.12). This allows determining whether there is a correlation between fertiliser application and development stages of rubber trees.

Table 6.12: Summary statistics of age of trees against fertiliser application strategy

No.	Description	Comparison between the applied fertiliser and the recommended amounts by extension services			
		Overall	**Less fertiliser**	**More fertiliser**	**Application fluctuates**
1	Skewness and Kurtosis test for normality of age of trees	43.87** *(N=430)*			
2	Median age of trees (years)	9.0	8.0	10.0	9.0
3	Kruskal-Wallis equality-of-populations' rank test of median age of trees	20.09**			
	Rank sum		19,480 *(N=115)*	28,450 *(N=122)*	42,596 *(N=188)*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

6.7.2 Age when Rubber Trees were First Tapped

In Appendix 1, the mean age of first tapping was over 5 years. There is a statistically significant negative correlation between latex yield and the long immature period ($p < 0.01$). Starting tapping at this stage is not too early, as a long immature period decreases latex production (Wibawa et al., 1997). Early tapping decreases the immature period of rubber trees and affects future growth and yield levels. At immature stages farmers obtain no income from latex and thereby the return on their investment is delayed. Thus they should be educated on the importance of the appropriate tapping age (Nugawela, 2009; Wijesuriya et al., 2007), because farmers prefer clones with early tapping girth diameter and high initial yield to clones with high late yield (Venkatachalam et al., 2013). Early tapping girth diameter and high initial yields are considered as early return attributes.

6.7.3 Planting Density

The stand density is an important indicator that can affect latex yield of the small-scale rubber sector due to competition for soil nutrients (Wijesuriya et al., 2007). The mean stand density in the survey area was about 528 rubber trees per ha. This is within the recommended range of 400 to 600 rubber trees per ha to avoid losses because of droughts, heavy winds, root diseases and dryness of tapping panels (Barlow et al., 1994). Very high (more than 800) or low (less than 150) planting density could cause root disease problems and low latex yield, respectively (Purnamasari et al., 2002; Wibawa et al., 1997). The number of tapped trees per ha determines latex yield of a rubber plantation (Viswanathan, 2008). This number tends to decrease in time because of damage by wind. Therefore, when farmers decide to choose clones they can expect attributes such as resistance to droughts, heavy winds and plant diseases. Planting density used by rubber farmers was found to be higher than in rubber estates, because rubber farmers often attempt to maximise their returns to land and labour (Barlow & Muharminto, 1982).

This section tests whether stand density among rubber farm households is statistically different across the three provinces.

Table 6.13: Summary statistics of stand density in the three provinces

No.	Description	Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Skewness and Kurtosis test for normality of density	70.70** *(N=415)*			
2	Median density (trees per ha)	550.0	550.0	500.0	550.0
3	Kruskal-Wallis equality-of-populations' rank test of median density	59.73**			
	Rank sum		26,590 *(N=144)*	21,802 *(N=131)*	37,929 *(N=140)*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

There is evidence from the field survey that the median stand density is different across the three provinces based on the Kruskal-Wallis equality-of-populations rank test of median density ($p < 0.01$). The median density in Binh Phuoc and Tay Ninh was highest (550 trees), followed by Dong

Nai (500 trees) (Table 6.13). Stand density may reflect latex yield levels of plantations. These rankings of density appear to be quite consistent compared to the rankings of latex yield in Table 6.1. There is a statistically significant positive correlation between latex yield and density from the survey data ($p < 0.01$) (Appendix 1).

6.7.4 Rubber Farming Systems

A monoculture system grows only rubber trees, whereas a multiculture system includes intercropping between rubber trees and other crop types. According to Kurukulasuriya and Mendelsohn (2007a) and Mendelsohn and Seo (2007), crop choices are climate-sensitive. In practice, intercropping usually occurs only the first three years of rubber plant establishment, before intercrops are shadowed by mature rubber trees (Barlow & Muharminto, 1982; Wibawa et al., 1997). About 39.7 per cent of the farmer households in the sample chose multiculture systems (Appendix 1). This choice is important because the intercrop may influence adaptation (Adesina & Chianu, 2002), through positive effects on on-farm income, soil conservation and plant nutrition (Rodrigo & Balasooriya, 2009). Intercropping may improve rubber tree growth, latex yield as well as family income (Wijesuriya & Thattil, 2005). "Instead of negative effects of crop competition on the growth of rubber, reported earlier, the new studies showed that rubber is actually benefited from intercropping" (Rodrigo & Balasooriya, 2009, p. 45). Therefore, crop diversification is considered as insurance against climate variability (Adger et al., 2003; Charles & Rashid, 2007). Small-scale rubber farmers are highly vulnerable to market uncertainties, but intercropping can raise their resilience (Viswanathan, 2008; Wijesuriya et al., 2007).

Crop choices are affected by several factors, and they influence farm management practices. The use of light, water and nutrients affects the performance of rubber trees and intercrops in different ways. Criteria for choosing intercrops with rubber trees include the ability to use these crops for household consumption, the acceptability for intercropping with rubber trees, the improvement in family income, and shorter periods for harvest (Wijesuriya & Thattil, 2005). In the case of Sri Lanka, Viswanathan (2008), Rodrigo and Balasooriya (2009) and Wijesuriya and Herath (2009) found that the institutional contexts, socio-economic conditions, natural rubber market demand and urbanisation affected choices between monoculture and multiculture systems.

Rubber farm size also affects choices of intercropping with other plants among Sri Lankan rubber farmers. Rubber farmer households with less land are likely to grow mixed crops, while farmer households with more land are likely to grow a rubber crop only (Senevirathna et al., 2010). This study does not find such evidence.

6.7.5 Labour Use

This section tests whether latex yield of rubber farm households is statistically different across labour use.

Labour is divided into family and hired labour. About 65.4 per cent of the farmer households in the sample used hired labour on their rubber plantations (Appendix 1). There is evidence that the farmers hiring labour have a higher probability of obtaining higher latex yield than others. The median of the group hiring labour is 2.0 tonnes/ha, and the median of the group not hiring labour is 1.8 tonnes/ha. The hypothesis that the medians of latex yields are the same across the two categories of labour use is rejected by the two-sample Wilcoxon rank-sum (Mann-Whitney) test of median yield ($p < 0.01$) (Table 6.14). However, tappers who are family members sometimes bring higher efficiencies to rubber cultivation, compared with hired tappers (Wijesuriya et al., 2011).

Table 6.14: Summary statistics of yield against labour hiring

No.	Description	Overall	Family labour	Hired labour
1	Skewness and Kurtosis test for normality of yield	8.21* *(N=405)*		
2	Median yield (tonnes/ha)	2.0	1.8	2.0
3	Two-sample Wilcoxon rank-sum (Mann-Whitney) test of median yield			
	z-statistic	-2.84**		
	Rank sum		23,130 *(N=131)*	56,670 *(N=268)*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Besides higher years of schooling (Table 6.9), the farmer households that have convenient access to extension services and larger farms have a higher probability of hiring labour. This section tests whether farm size among rubber farm households is statistically different across labour use.

Table 6.15: Summary statistics of farm size against labour hiring

No.	Description	Overall	Family labour	Hired labour
1	Shapiro-Wilk W test for normal data of farm size	11.15** *(N=430)*		
2	Median farm size (ha)	3.0	1.8	4.0
3	Two-sample Wilcoxon rank-sum (Mann-Whitney) test of median farm size	-7.80**		
	z-statistic			
	Rank sum		21,276 *(N=145)*	66,714 *(N=274)*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

There is evidence that the farmer households with large farms have a higher probability of hiring labour than others. The median of the group hiring labour is 4.0 ha, and the median of the group not hiring labour is 1.8 ha. The hypothesis that the medians of farm sizes are the same across categories of labour use is rejected by the two-sample Wilcoxon rank-sum (Mann-Whitney) test of median farm size ($p < 0.01$) (Table 6.15).

Table 6.16: Summary statistics of agricultural extension against labour hiring

No.	Description	Overall	No access to extension	Access to extension
1	Labour use (%)			
	Family labour	34.69	*41.29* *(N=83)*	*28.57* *(N=62)*
	Hired labour	65.31	*58.71* *(N=118)*	*71.43* *(N=155)*
2	Chi-squared test for relationship between labour hiring and extension	7.45**		

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Rubber trees are one of the most labour-intensive crops, and labour competition may occur with other crops at harvest (Bell, 1986). Demand for labour in rubber plantations is year-round (Rodrigo et al., 2009). Poor farmers tend to use more family labour for most of their agricultural activities. In contrast, better-off farmers with relatively large farms often use more hired labour (Dung, 2007).

Rubber farm households' income level influences the employment of hired labour or family labour (Wijesuriya et al., 2007).

Section 6.6.4 finds that farmers with higher years of schooling have a higher probability of hiring labour than others. In Table 6.16, the probability that households with access to extension services would hire labour is higher than that of households with no access to extension services in the sample. There were 155 households with access to extension who hired labour (71.4 per cent), while 118 households with no access to extension hired labour (58.7 per cent). There is a statistically significant relationship between labour hiring and extension according to the Chi-squared test ($p < 0.01$). Households with better access to extension services, rural infrastructure or within a non-poor community may have high demand for hired labour (Yu et al., 2013), because socio-economic differences among communities lead to their different behaviour in natural and human systems (Liu et al., 2007).

6.8 Income Vulnerability

This section tests whether yield losses among rubber farm households is statistically different across the three provinces.

Table 6.17: Summary statistics of yield loss in the three provinces

No.	Description	Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Skewness and Kurtosis test for normality of yield loss	45.41** *(N=397)*			
2	Median yield loss in the previous year (%)	15	20	20	10
3	Kruskal-Wallis equality-of-populations' rank test of median yield loss	163.80**			
	Rank sum		38,871 *(N=143)*	25,826 *(N=114)*	14,307 *(N=140)*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

It is assumed that people may distinguish between potential impacts occurring before adaptation and residual impacts occurring after adaptation to climate change (Lal et al., 2001). Wibawa et al. (1997) investigated rubber farmers' perception of damage and benefits of climate change on their farming activities. The mean loss of latex yield in 2013 was about 17 per cent in the surveyed sample

(Appendix 1). There is a statistically significant difference in median yield loss in the previous year across the three provinces. The hypothesis that medians of yield loss in the previous year are the same across the three provinces is rejected based on the Kruskal-Wallis equality-of-populations rank test of median yield loss ($p < 0.01$). The yield loss was highest in Binh Phuoc and Dong Nai and was twice as high as Tay Ninh (Table 6.17). Latex variability was also higher in these two provinces, followed by Tay Ninh (Figure 6.1). A high variability of yield can at times a loss.

In Table 6.18, about 36 per cent of farmers in Binh Phuoc and 17 per cent of farmers in Dong Nai considered the climate impacts on rubber production very severe, whereas only 4 per cent of farmers in Tay Ninh considered them very severe. Other levels of severity are quite similar among farmers across the three provinces. This evidence may explain the magnitude of yield loss across the three provinces in Table 6.17. There are statistically significant differences in proportions of the severity assessment of climate impacts on rubber production by farmer households across the three provinces according to the Chi-square test ($p < 0.01$).

Table 6.18: The severity of climate impacts on natural rubber production

No.	Level of severity	Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Very severely affected (%)	18.91	*35.62*	*16.79*	*3.57*
2	Severely affected (%)	53.19	*50.68*	*53.28*	*55.71*
3	Moderately affected (%)	16.78	*9.59*	*13.14*	*27.86*
4	Slightly affected (%)	9.69	*4.11*	*12.41*	*12.86*
5	Do not know (%)	1.42	*0.00*	*4.38*	*0.00*
	Chi-square test for differences in proportions of the severity assessment of climate impacts on rubber production	75.15**			

*: $p < 0.05$ and **: $p < 0.01$

The Fisher's exact test does work for this case because of the memory limited.

Source: Estimates using the survey data

A study in Sri Lanka showed that farmers could perceive the factors impacting on rubber tree growth and latex yield (Wijesuriya & Thattil, 2005). Farmer perception in the sample of key climate variables is presented in Section 6.9.

6.9 Perception of Climate Change and Variability

Understanding farmers' perception of climate change and adaptation strategies at the farm level helps understand what affects their decisions when choosing adaptive measures (Charles & Rashid, 2007; Smit et al., 2001). Chapter 5 helps consolidate findings of climate change and variability in the study area, while the basis of farm-level factors affecting farmer households' decisions when choosing adaptive measures was analysed in Chapter 3 and this chapter. Chapter 7 focuses on adaptation strategies at the farm level in the study area. Hence, Chapter 8 estimates the determinants that affect their decisions when choosing adaptive measures.

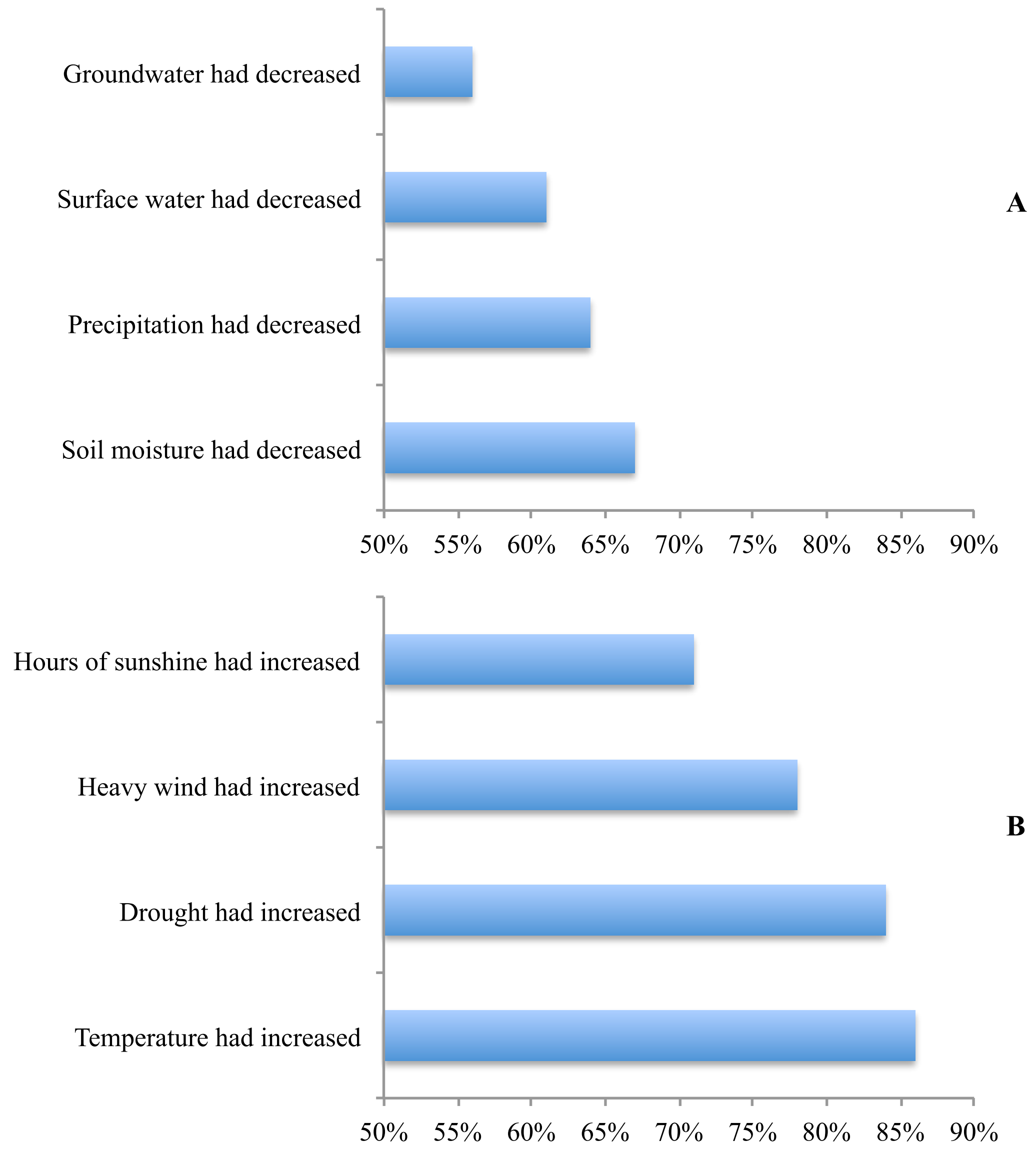

Figure 6.8: Perceptions of changes in climate variables by farmers in the study area

Source: Estimates using the survey data

The rubber farmers were asked about the current status of weather and climate, in comparison with the past. For the sake of simplicity, the respondent was asked to show his or her agreement of changes in local climatic conditions over the past 20 years. About 97.2 per cent of the farmers interviewed said their local climatic conditions had changed over the past 20 years (Appendix 1). Most of them said that groundwater (56 per cent), surface water[55] (61 per cent), precipitation (64 per cent) and soil moisture (67 per cent) had decreased over time (Figure 6.8.A). Most of them also said that hours of sunshine[56] (71 per cent), heavy wind[57] (78 per cent), drought[58] (84 per cent) and temperature (86 per cent) had increased over time (Figure 6.8.B). These percentages show evidence that rubber farmers in the sample have a strong perception of climate change and variability. These figures are in line with a similar assessment of Van et al. (2015) in a case study of rice farmers in the Northern Central Coast of Vietnam. Less than 9 per cent of the farmers in the sample observed no changes in temperature, precipitation and drought.

Farmers' perception of changes in climatic conditions at their locality and how well the farmers adopt adaptive measures are questions addressed in Chapter 7. It is worth investigating whether farmers have high awareness of adaptive measures, even if their adoption of adaptive measures is low (Ongley, 1996). Incorrect awareness of the effect of climate variables on rubber cultivation-related activities results in low adoption of adaptive measures, which contributes to low latex production, yield and quality. There is resource wastage in the small-scale farm sector due to poor awareness and improper adoption of technical recommendations. This wastage may occur in rubber planting, nursing and harvesting stages (Wijesuriya et al., 2011).

The perception of changes in local climatic conditions is compared among the rubber farmers in the study area. The available data on hydro-meteorological features from 1978 to 2012 in Chapter 5 verify matching of rubber farmer perception of climate change. If farmer perceptions of patterns of

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55 Available groundwater and surface water is a vital factor in determining the impacts of climate change. Precipitation, the commencing time of growing seasons and length of growing seasons are critical in determining if climate change affects agriculture positively or negatively (Kurukulasuriya & Rosenthal, 2003; Rodrigo et al., 2009).

56 Intensive sunlight during winter could affect photosynthesis of young rubber trees and thereby damaging their growth (RRII, 2010).

57 DRC of different clones is affected differently by wind velocity (Priyadarshan, 2003).

58 The presence of droughts or storms at any stage of the rubber growing process may impact directly on rubber tree growth and latex yield. For instance, storms directly affect tapping days, and they disrupt the harvest because of rubber-tree trunks being twisted off (RRII, 2010), while droughts cause almost the death of rubber trees (Wijesuriya et al., 2011).

weather, climate and seasons are not strong, planning for cultivation becomes more difficult (McElwee, 2010).

Although the influence of climate variables on latex yield is different at different periods of time and in different regions (RRII, 2010), about 98.6 per cent of the farmers in the sample said climate variables affected their latex yield negatively. About 72 per cent of the farmers assessed the effect of climate variables on their latex yield as severe to very severe. Only 1.4 per cent of them did not note any effects (Table 6.18).

Table 6.19: Farmer perceptions of climate variables by province

No.	Climate variables	% of farmers could not observe trends	% of farmers could observe trends			Fisher's exact test
			Binh Phuoc	Dong Nai	Tay Ninh	
I	**Increased trend**					
1	Hours of sunshine	16.26	73.61	86.51	54.41	**
2	Heavy wind	1.95	78.32	86.26	69.34	**
3	Drought	3.66	82.64	86.05	82.48	$p > 0.1$
4	Temperature	4.84	92.47	86.15	78.83	**
II	**Decreased trend**					
5	Soil moisture	14.43	75.17	71.09	55.88	**
6	Precipitation	2.90	51.37	65.91	76.47	**
7	Surface water	25.61	70.55	71.65	40.88	**
8	Groundwater	30.49	61.81	68.22	38.69	**

*: $p < 0.05$ and **: $p < 0.01$

Percentages do not add up to 100 because they refer only to farmers who observed trends correctly.

Source: Estimates using the survey data

In Table 6.19, the perception among most farmers of trends of key climate variables is quite consistent across the three provinces. However, farmers across the three provinces stated their different assessments of most climate variables according to the Fisher's exact test ($p < 0.01$). This means that they observed different trends of these variables across the three provinces, excepting drought status according to the Fisher's exact test ($p > 0.1$). Droughts in the past could deeply affect farmers in the study area, so they could remember such weather events. Numbers of rubber farmers in Tay Ninh perceived correctly trends of key climate variables were less than in Binh Phuoc and Dong Nai (Table 6.19). This may be explained by mean years of schooling of farmers in the sample in Tay Ninh (8.96 years) being less than in Binh Phuoc (10.21 years) and Dong Nai (9.77 years)

(Appendix 1). There are considerable differences in patterns of climate variables in each province (Chapter 5), so farmers in the sample stated these patterns differently. Fewer than 31 per cent of the farmers did not know about changes in hours of sunlight, soil moisture, underground and surface water, and < 5 per cent of the farmers did not know about changes in temperature, precipitation, drought and heavy wind. Changes in temperature, precipitation, drought and heavy wind seem more easily observed than the other variables above.

Caring for rubber trees is very important, particularly in fighting diseases of bark and leaves. These diseases may cause dryness of the tapping panel, or they may cause leaves to fall or develop holes resulting in reduced photosynthesis. Disease incidence can decrease DRC in latex (Nugawela, 2006; Wibawa et al., 1997). If the diseased tree is not treated, it may die (Diaby et al., 2011).

Table 6.20: Summary statistics of common plant diseases in the three provinces

No.	Description	Overall	Binh Phuoc	Tay Ninh	Dong Nai
1	Stem and root diseases (%)	33.10	*34.93*	*17.52*	*46.43*
2	Pink fungi (%)	43.74	*45.21*	*62.04*	*24.29*
3	Tapping panel dryness (%)	23.17	*19.86*	*20.44*	*29.29*
	Chi-square test for differences in proportions of the common-diseases assessment by province	43.78**			

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Common diseases of rubber trees have been found via consultation with agricultural extension officials and farmers who specialise in growing rubber trees in Southeast Vietnam. Diseases may consist of (i) stem and root diseases resulting in falling leaves, (ii) pink fungi disease resulting in bark dryness and plant death and (iii) tapping panel dryness resulting in low latex yield. The most challenging diseases to farmers in the sample were pink fungi disease (43.7 per cent), stem and root disease (33.1 per cent) and tapping panel dryness (23.2 per cent). The structure of importance between diseases is different across the three provinces. Pink fungi disease (45.2 per cent) and stem and root diseases (34.9 per cent) were the most important diseases in Binh Phuoc. Pink fungi disease (62.0 per cent) was the most important in Tay Ninh, while stem and root diseases (46.4 per cent) and tapping panel dryness (29.3 per cent) were the most important diseases in Dong Nai (Table 6.20). There is a statistically significant difference in proportions of the common diseases across the three provinces according to the Chi-square test ($p < 0.01$).

6.10 Discussion and Conclusion

Some key points in this chapter are in line with the findings in Chapter 5. Most farmers interviewed said their local climatic conditions had changed over the past 20 years. Their perceptions of trends of such climate variables are quite different across the three provinces. This shows a strong perception among rubber farmers of climate change and its variability. Higher education was associated with better perception of changing climatic conditions.

Most farm households in the sample have mature rubber trees, so they could receive income from rubber. Difference in latex yield across the three provinces is shown clearly at the farm level, although this is not present at the provincial level. However, the rankings of latex yield across the three provinces remain the same. Binh Phuoc, followed by Tay Ninh, generated the highest yield compared with Dong Nai. Latex variability in the sample was also higher in Binh Phuoc and Dong Nai. A high variability of yield can translate into income vulnerability.

Among numerous positive factors like clones sourced from private nurseries, skilled labour and *acrisols* soil types appear to be compatible with yield improvement of rubber trees. Stand density is associated with differences in latex yield, but there are no strong correlations between latex yield and density across the three provinces. A range of other factors have indirect relationships to latex yield through their relationships with on-farm skilled labour employment, such as education level, farm size and access to extension. There is evidence that farmers with higher education have a higher probability of hiring labour than others and participating in social commitments, and having main occupations other than agriculture. Employment of skilled labour on farms also captures higher yield levels compared with those using only family labour. Households that have access to extension services and larger farms have a higher probability of hiring labour than others. The remaining factors presented in chapters 3 and 6 are further concluded in chapters 7 and 8.

The yield loss caused by climate change and variability was 17 per cent on average in 2013, but there is a difference in yield loss across the three provinces. Farmers in the sample perceived this risk resulting from climate change and variability. Most farmers said climate variables affected their latex yield negatively, with effect ranging from severe to very severe. They concurred that severe to very severe climate impacts caused losses in yield thereby creating income vulnerability, because high latex yield has a statistically strong correlation to high net profit. Loss percentages are higher in Binh Phuoc and Dong Nai with higher variability in yield. Interestingly, a considerable number of farmers in Binh Phuoc and Dong Nai observed very severe climate impacts on their farms, whereas only a small number of farmers in Tay Ninh observed very severe climate impacts. Such findings imply differences in yield losses caused by the severity of climate change and variability in the study area.

Most farm households are smallholders (rubber land size < 5 ha), and they use most of their land for growing rubber trees. Therefore, yield losses associated with prolonged challenges, in terms of market uncertainty and latex-price decline, hurt deeply this small-scale rubber sector. Although most farmers have convenient access to irrigation facilities, the main access to irrigation facilities for agricultural production is from groundwater. Expanded irrigation could result in groundwater depletion in this area. A small proportion of farmers use electricity at their plantations.

Chapter 7 Adaptation strategies of Farmers and Constraints to Adaptation at the Farm Level in Southeast Vietnam

7.1 Introduction

In previous chapters, climate change and variability are shown to affect latex yield at both the provincial and farm levels. The adverse impacts are clearly seen at the farm level through farmer households' losses in latex yield. Farmers perceived that climate change and variability were present, and their actual impacts occurred negatively. There is evidence that nearly all of the farmer households in the sample used adaptive measures (Appendix 1). This chapter answers the sixth question of whether farmer households in the study area experienced an adaptive deficit. It studies methods of adaptation which have been adopted or have a propensity to be adopted by farmer households who perceived or anticipated climate impacts.

Table 7.1: Adaptive measures being practised at the farm level and their attributes

No.	Adaptive measures	ID	Attributes
1	Using proper ground preparation	1	Resistance to drought
2	Choosing proper clones, planting materials and sound crop establishment	2	Resistance to heavy winds
3	Altering the fertiliser application strategy	3	Resistance to plant diseases
4	Employing water-saving irrigation technologies	4	Skilled labour availability
5	Applying water conservation techniques	5	Capital availability
6	Applying soil conservation techniques	6	Time availability
7	Employing rain guard technology	7	Property rights
8	Applying correct tapping techniques	8	Application of knowledge
9	*No adaptation*	9	Institutions
		10	Market access
		11	Early yields
		12	Latex yield
		13	Latex quality
		14	Technical and economic efficiency

Each of the eight adaptive measures above includes a 14-attribute set.

ID numbers for each attribute are used later to relate adaptive measures to their attributes (see Table 7.3).

Source: Author's classification

In the context of rubber production in Southeast Vietnam, there are already eight common adaptive measures being practised by farmers. The list of adaptive measures for rubber trees were compiled from various studies including Barlow and Muharminto (1982), Bell (1986), Wibawa et al. (1997), Purnamasari et al. (2002), Priyadarshan (2003), Wijesuriya and Thattil (2005), Nugawela (2006), Wijesuriya et al. (2007), Nugawela (2008a), Nugawela (2008b), Nugawela (2009), Samarappuli and Wijesuriya (2009), Perera and Seneviratne (2009), Wijesuriya and Dissanayake (2009), Wijesuriya et al. (2011). These were then confirmed through consultation with experts and farmers in the study area. Most of the key informants interviewed, who specialise in the Vietnam rubber industry and are rubber farmers in Southeast Vietnam, agreed with the significance of research on these adaptive measures and the use of 14 related attributes. It is true that most of these practices should be followed anyway, but climate change brings urgency to the adaptation decision. Without climate change farmers could continue to operate using traditional methods and still make a living, with climate change those farmers who do not adapt may go out of business. Climate change also influences specific aspects of the adaptation decision; for example, the types of clones that should be adopted are influenced by the type of changes expected in a particular region in terms of wind, rainfall and temperature.

The adaptive measures in Table 7.1 can be classified into three different groups based on plant developmental stages (measures *1* and *2* during planting; measures *3–6* during nursing; and measures *7* and *8* during harvesting). The key 14 attributes are important to rubber farmer households' choice decisions on adaptive measures. The respondent's preference for particular adaptive measures is linked with a set of desirable attributes, since each choice is usually related to several attributes (Birol et al., 2007; Falck-Zepeda et al., 2011). For each adaptive measure chosen in Table 7.1, the respondent was requested to point out what attributes were of concern.

Farmers could state their selection combinations among eight measures or simply answer "no adaptation". Farmers who had chosen to adapt were requested to give the researcher their stated preferences for related attributes of each measure using a 5-point Likert scale and then could indicate constraints to adaptation.

The respondent was requested to identify appropriate attributes for each adaptive measure using a 5-point Likert scale to estimate the strength of the influence for each of the attributes. The respondent's answers of the strength of each attribute were coded using numbers from 1 to 5 depending on the agreement level (1 = *strongly disagree*, 2 = *disagree*, 3 = *neutral*, 4 = *agree* and 5 = *strongly agree*).

Ideally, a respondent would assess the 14 attributes for all adaptive measures chosen but this was not feasible in the available time. Therefore, the respondents were asked to assess the 14 attributes for only the most important adaptive measure to avoid confusion. The most important adaptive measures were determined based on the time and resources that farmers expected to devote to particular practices in adapting to climate change and climate variability. The respondents were first asked to choose the most important adaptive measure from the list of the eight (left column in Table 7.1 excluding "no adaptation"). They ranked adaptive measures in order, from 1 to 8 (or 9 to indicate no adaptation). This helps fit the models to analyse farmer preferences for adaptive measures. It also provides additional information presented in Section 7.2 on rubber farmer households' priorities among the given adaptive measures.

Table 7.2: Adaptive measures being practised at the farm level by province

No.	Adaptive measures (N = 426)	% farmers considering adaptive measures important			
		Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Using proper ground preparation	2.82	2.74	4.29	1.43
2	Choosing proper clones, planting materials and sound crop establishment	**32.63**	**30.82**	**47.86**	**19.29**
3	Altering the fertiliser application strategy	**8.69**	**10.96**	**9.29**	**5.71**
4	Employing water-saving irrigation technologies	0.70	0.00	0.71	1.43
5	Applying water conservation techniques	3.29	3.42	2.86	3.57
6	Applying soil conservation techniques	1.88	2.05	2.86	0.71
7	Employing rain guard technology	**23.71**	**33.56**	**7.14**	**30.00**
8	Applying correct tapping techniques	**26.29**	**16.44**	**25.00**	**37.86**
9	*No adaptation*				
	Chi-squared test for differences in proportions choosing the most important adaptive measures by province	63.18**			

*: $p < 0.05$ and **: $p < 0.01$

The Fisher's exact test does work for this case because of the memory limited.

Source: Estimates using the survey data

The purpose of this chapter is to analyse farmer segments' adaptive behaviour, and the determinants of their choice behaviour. Farmers may be more or less risk averse. They may also look to achieve input efficiency or be more concerned with output efficiency (Barlow & Muharminto, 1982). For example, if latex production is not profitable to farmers, they can maintain rubber trees for the purpose of timber production. They face trade-offs between profit and risk in their rubber cultivation planning, which are driven by two approaches: (i) profit maximisation in response to changes of socio-economic conditions and (ii) risk minimisation in response to conditions of climate change and variability. For instance, most poor farmers place a higher value on risk minimisation rather than on profit maximisation (Dung, 2007; Wibawa et al., 2006). Farmers in the low-income countries are sometimes regarded as satisficers (Alauddin & Sarker, 2014); they can look on with indifference among adaptive measures.

In Table 7.2, three adaptive measures were most preferred: proper rubber clones, planting materials and sound crop establishment (chosen by 32.6 per cent), rain guard technology (23.7 per cent) and correct tapping techniques (26.3 per cent). There is a statistically significant difference in the proportions of respondents choosing the most important adaptive measures across the three provinces, according to the Chi-squared test ($p < 0.01$). Altering the fertiliser application strategy was also a preferred measure (8.69 per cent). Water-saving irrigation technologies were the least adopted, followed soil conservation techniques and proper ground preparation. Water conservation techniques were also less adopted. There is almost no evidence of an adaptive deficit; only four out of 430 households in the sample stated "no adaptation". Salient features of each measure are summarised in Table 7.3.

Table 7.3: Adaptive measures and desirable attributes

Adaptive measures (N = 426)	**% farmers considering attributes important** (at levels of agree and strongly agree)													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	1.9	2.3	1.4	2.3	2.3	2.1	2.6	1.9	1.2	0.9	1.9	2.1	2.3	2.1
2	**29.8**	**25.1**	**29.8**	**13.8**	**15.0**	**15.5**	**17.1**	**12.7**	**9.9**	**18.3**	**23.5**	**31.5**	**30.8**	**23.5**
3	4.2	4.5	0.2	3.3	4.5	3.5	2.3	0.0	0.5	3.1	0.0	7.0	7.5	4.9
4	0.7	0.7	0.0	0.2	0.7	0.2	0.0	0.0	0.0	0.5	0.0	0.7	0.7	0.7
5	0.7	0.7	0.0	1.9	1.2	2.3	0.7	0.0	0.9	0.9	0.0	3.1	3.3	1.6
6	0.7	0.7	0.0	1.4	0.9	1.6	1.4	0.0	0.0	0.9	0.0	1.2	1.6	1.6
7	**15.3**	**15.3**	0.0	**13.8**	**14.1**	**13.4**	0.0	**10.1**	**0.9**	**16.0**	0.0	**22.1**	**22.3**	**16.7**
8	**12.4**	**12.4**	0.0	**23.5**	**15.0**	**13.8**	0.0	**16.0**	**6.1**	**12.4**	0.0	**25.1**	**25.8**	**22.8**

Source: Estimates using the survey data

In Table 7.3, about a third of the farmer households in the sample considered most attributes important (at levels of agreement and strong agreement). This evidence consolidates the validity of the 14-attribute set. Farmer households in the sample were less interested in attribute 9 (institutional supports) among the adaptive measures. The explanatory power of attributes among adaptive measures is assessed in Chapter 8. The importance of attributes in distinguishing different behaviour groups of farmer households is also assessed in Chapter 8.

7.2 Adaptation Strategies of Farmers

This study refers to adaptation strategies without distinguishing between adaptation strategies and coping strategies. These two definitions appear only to make clear the temporal dimension of strategies. The distinction of temporal effects of adaptive actions at the farm level may be relaxed, because poor farmers sometimes use daily simple actions. Some common simple actions become adaptive solutions in the long term, so temporal dimensions are variable. For example, when tapping occurred during the rains farmers would cover latex collecting cups with plastic bags as a coping action. This simple innovation has evolved to use of rain guards.

Based on a temporal dimension of adaptive measures, the eight adaptive measures can be categorised as follows: proper ground preparation (measure 1), proper rubber clones, planting materials and sound crop establishment (measure 2), altering the fertiliser application strategy (measure 3), water conservation techniques (measure 4), water-saving irrigation technologies (measure 5), soil conservation techniques (measure 6) and correct tapping techniques (measure 8) all being adaptive actions. Rain guard technology (measure 7) is a coping action.

7.2.1 Using Proper Ground Preparation

Site preparation is an important adaptive measure to climate change (Yu et al., 2013), as it facilitates the growth and potential yield of rubber trees (Adesina & Chianu, 2002; Barlow & Muharminto, 1982; Diaby et al., 2011; Kurukulasuriya & Rosenthal, 2003; Nugawela, 2008a, 2008b; Priyadarshan, 2003; Purnamasari et al., 2002; Rodrigo et al., 2009; Samarappuli & Wijesuriya, 2009; Senevirathna et al., 2010; Smithers & Blay-Palmer, 2001; Venkatachalam et al., 2013; Vien, 2008; Wijesuriya & Dissanayake, 2009; Wijesuriya et al., 2007; Wijesuriya et al., 2011; Wijesuriya & Thattil, 2005).

Site preparation can prevent soil degradation and can reduce weed growth as well as weed-related yield losses. It can lessen the damage to rubber tree trunks from heavy winds. Site preparation under technical standards requires considerable investment of capital and time over a limited period of time (Dung, 2007; Greenland, 1997; McElwee, 2010; Nugawela, 2008a). Technical standards indicate appropriate row distances and slopes. Slopes of 10–15 degrees, for example, help surface water run off. This requires land preparation such as terraces to conserve soil moisture. This method is applicable to new planting and replanting, so security of tenure may stimulate farmer households to invest in land preparation. Flat areas require small drains and gutters to collect surface and rain water. Inundated areas can cause diseases of leaves, trunks and bark as well as affecting the tree growth and latex quality.

However, in Table 7.2, only a small portion of the farmer households considered proper ground preparation the most important (2.8 per cent).

7.2.2 Choosing Proper Rubber Clones, Planting Materials and Sound Crop Establishment

Clone selection, planting materials and crop establishment influence the growth and potential yield of rubber trees as well as reducing weed growth and weed-related yield losses (Charles & Rashid, 2007; Diaby et al., 2011; Greenland, 1997; Nugawela, 2006, 2008b; Priyadarshan, 2003; Purnamasari et al., 2002; Viswanathan, 2008; Wibawa et al., 1997; Wijesuriya & Dissanayake, 2009). For instance, Wibawa et al. (1997) reported that rubber tree girth diameter of BPM24 clone in clean-weeded rubber plots was twice as large as weed-invaded rubber plots.

Crop establishment is a technical term used to describe how rubber trees are planted on plantations. It can include modifying the length of the growing periods and changing planting and harvesting dates (Charles & Rashid, 2007). Farmers sometimes face trade-offs between time availability and financial costs for crop establishment. Sound crop establishment helps ensure that critical growth stages do not coincide with expected severe climatic conditions (Charles & Rashid, 2007; Nugawela, 2008b).

New rubber clones have attributes such as high temperature resistance, drought tolerance, and resistance to diseases and heavy winds. For instance, Guayule is a drought resistant clone that is ideally suited to Australia's climatic conditions. Nevertheless, it requires dry conditions for high DRC but enough water for its growth (Bell, 1986). Each clone usually requires different cultivation techniques and schedules in order to take advantage of the prevailing natural conditions, which increase the probability of survival. Different clones are affected differently by crop management practices. Use of clones is also compatible with new planting and replanting, so security of tenure, appropriate knowledge, affordability of clones, capital and time availability influence farmer households' investment in clones. For example, not as cheap as bare root budded stumps, poly-bagged plants are easily established on rubber plantations (Wijesuriya et al., 2007).

Table 7.4: Use of clones at the farm level

No.	Clone options (N = 407)	% of farmers that adopted	Binh Phuoc	Dong Nai	Tay Ninh
1	RRIV4	**47.9**	**33.3**	**27.5**	**80.7**
2	BP260	**14.3**	**20.4**	**23.3**	0.0
3	BP235	**6.6**	**10.9**	5.0	3.6
4	Lai Hoa 90 952	**5.2**	0.7	**16.7**	0.0
5	RRIV4 & BP235	3.2	**8.8**	0.0	0.0
6	RRIV4 & VM515	2.7	0.7	4.2	3.6
7	RRIV4 & BP260	2.5	**5.4**	1.7	0.0
8	VM515	2.2	1.4	0.0	5.0
9	DK4	1.2	3.4	0.0	0.0
10	33 other combinations	14.3	15.0	21.7	7.1

Source: Estimates using the survey data

There were about 42 types of planted rubber clones available in the study area (Table 7.4). The vast majority of preferred clones are RRIV4 (over 47.9 per cent) and BP260 (over 14.3 per cent). RRIV4 is particularly popular in Tay Ninh (80.7 per cent), but no farmers in the sample in Tay Ninh used BP260. BP235 is also popular in Binh Phuoc (10.9 per cent) and Lai Hoa 90 952 in Dong Nai (16.7 per cent).

In Southeast Vietnam, rubber farmer households may replant new rubber clones. For example, RRIV5 develops fast and has high latex yield and quality that also can resist hot weather. Its immature period is shorter, from seven years down to five years. Therefore, growers obtain early yields. Some new clones have 1.5 times more latex yield compared to other clones, for example, Lai Hoa 90 952. RRIV4 and BP260 are popular in Southeast Vietnam. Nonetheless, BP260 has limitations of yield, and RRIV4 has exposure to Corynespore and less resistance to heavy winds. BP235 and Lai Hoa 90 952 have been grown in Southeast Vietnam, and they have advantages in less exposure to diseases and high DRC. Lai Hoa 90 952 also has some other useful characteristics of rapid tree growth and high latex yield. Currently, RRIV4 is recommended as a clone that needs to be replaced. Some local rubber companies have recommended several sets of clones during the period 2011–2015. They specify clones based on location, area planted and topography.

Average latex yield is distinctly higher in clones than in wildlings[59]. The clone is also known to grow about 30 per cent faster compared to a wildling (Purnamasari et al., 2002). Although a wildling

[59] A wildling, or unselected seedling, is planted from seed dispersed from nearby rubber trees.

usually has lower quality, higher yield variation, less virgin bark and less renewal of accessible bark than a clone (Purnamasari et al., 2002), it has no initial cost other than time used to collect the seed. Hence, there are no benefits from keeping a wildling rubber tree for as long as a GT1[60] clone (Barlow & Muharminto, 1982; Grist et al., 1998; Wibawa et al., 1997). There are only three households in Dong Nai over the survey area growing GT1.

New rubber clones that provide higher yields are worth investigating and recommending to rubber farmers, but increased yield accompanied by higher yield variation introduces higher risks to rubber farmers (Senevirathna et al., 2010). Establishment of high performance clones is a priority in some developing countries because they are homogenous and produce high yield. Obviously, it is important to establish productive clones from the start. Clones with early tapping girth diameter and high initial yield are likely to be preferred to clones with high late yield. Some clones that can withstand intensive tapping may be desirable in labour-abundant regions or in the small-scale rubber sector (Venkatachalam et al., 2013). Plantation owners may prefer to grow a mix of old clones, that are less efficient, with a small portion of recent clones in order to spread risks (Diaby et al., 2011). However, most small-scale farmers have difficulty adopting clonal technology because they lack the required knowledge (Dung, 2007; Lal et al., 2001; Lasco et al., 2011; Nugawela, 2009; Purnamasari et al., 2002).

7.2.3 Altering the Fertiliser Application Strategy

Nutrient management to replace nutrients used up by plants is very important. Insufficient supply of nutrients can reduce potential crop yield, while over supply may result in higher production costs and negative effects to the system and the environment[61] (Dung, 2007). Fertiliser is an important component of variable costs within the cost structure[62]. Fertiliser application (the timing, amount, type, rate, active concentration and method of application) affects tree growth and latex yield (Nugawela, 2006; Senevirathna et al., 2010; Wijesuriya et al., 2007; Wijesuriya & Thattil, 2005). In the past, rubber farmers hoed up ground to apply fertilisers and nutrients. Now they drill one-metric

[60] The GT1 clone has been the most common clone planted in Indonesia (Purnamasari et al., 2002).

[61] The intensive use of fertilisers could cause higher environmental consequences in terms of greenhouse gas emissions into the atmosphere or the risk of water pollution, because plants in general absorb only about fifty per cent of the nitrogen fertiliser applied. Fertiliser can pollute surface water and groundwater mainly by its nitrates content. The rest is discharged into the environment through runoff, leaching, erosion or gaseous emission (Dung, 2007).

[62] The cost structure of rubber cultivation depends mostly on farming activities (fertiliser application, weed control, site clearance and planting preparation occupying about 48 per cent), labour wages occupying (about 38 per cent) and other work (14 per cent) (Wijesuriya & Herath, 2009).

deep holes between two rubber trees to apply fertilisers and other nutrients. This method delivers the necessary nutrients to the roots.

Commercial fertilisers vary depending on nutrient mixtures and concentration, so all types of commercial fertilisers are converted into N, P and K nutrients for comparison (Dung, 2007). In practice, most small-scale farmers cannot measure the amount and balance[63] of nutrients because they lack the required knowledge (Dung, 2007; Lal et al., 2001; Lasco et al., 2011; Nugawela, 2009). Application of organic manure improves the survival rate of young budding plants after planting. It improves rubber tree growth, girth diameter growth and tapping ability, although tree age, planting density and site conditions also influence girth diameter growth. Within a given rubber variety or clone, latex yield is mainly determined by girth diameter (Samarappuli & Wijesuriya, 2009). Rubber farmers also apply microorganisms. Such practices can increase costs, but they improve latex yield and quality as well as the environment and soil fertility (Nugawela, 2008b). Among the essential nutrients, nitrogen (N), phosphorus (in the form of P_2O_5) and potassium (in the form of K_2O) are used in large amounts (Dung, 2007).

Fertiliser application may increase latex yield by about 20 per cent in less fertile soil, but the recommended quantity depends on the growth stage of rubber trees, types of clones, rain timing, cultivation conditions, biophysical status[64] as well as whether application occurs on soil or on foliar surfaces (Dung, 2007; Nugawela, 2008b; Wijesuriya et al., 2007). Low active concentrations of various agrochemicals are usually recommended for tapped rubber trees on virgin bark, but with higher concentrations on renewed bark. Inappropriate agrochemical application in different growth periods of rubber trees can result in adverse impacts (Nugawela, 2006). Farmers also decide on fertiliser application for their crop with varying levels of efficiency. The intensive use of chemical fertilisers is also because of the decreased ratio of fertiliser price over output prices (Dung, 2007; Minot & Goletti, 2000). Low fertiliser application is sometimes caused by low latex prices (Wijesuriya et al., 2007).

[63] NPK is with different rates (e.g. 16-16-8, 20-20-15). The number of 16-16-8 means that NPK fertiliser is used at a rate of 16 per cent N, 16 per cent P and 8 per cent K, accounting for 40 per cent of the total, with the 60 per cent consisting of clay.

[64] Biophysical status refers to natural factors and natural processes, such as precipitation, temperature, soil quality and water availability. These factors determine crop yields and externalities arising from the agrochemical use (Dung, 2007).

Table 7.5: Summary statistics of fertiliser use in the three provinces

No.	Description (N = 425)	Overall	Binh Phuoc	Dong Nai	Tay Ninh
1	Less than recommended (%)	27.06	*17.01*	*26.09*	*38.57*
2	More than recommended (%)	28.71	*27.21*	*18.84*	*40.00*
3	Application rate fluctuates (%)	44.24	*55.78*	*55.07*	*21.43*
	Chi-square test for differences in proportions of fertiliser application by province	47.97**			

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

The amount of fertiliser applied was compared with the amount recommended by extension services. There is evidence from the field survey that fertiliser-application is different across stages of rubber trees (Chapter 6). Fertilising in mature plantations helps raise latex yield and the regeneration of used bark, but application amounts are lower than in immature plantations (Wijesuriya et al., 2007). Farmer households in the sample applied less fertiliser on younger rubber trees (Table 6.12). Farmer households in the study area commonly used more N, P_2O_5 and K_2O than the extension recommendation (FAO, undated). About 29 per cent of the farm households in the sample applied more fertiliser than recommended by extension services in order to offset losses caused by climate variables, while 44 per cent said their application rate fluctuated. There are differences in proportions of fertiliser application across the three provinces according to the Chi-square test ($p < 0.01$) (Table 7.5).

In Table 7.3, no farmer households in the sample considered attribute 8 (application of knowledge) and attribute 11 (early returns) important against adaptive measure 3 (altering the fertiliser application strategy).

7.2.4 Employing Water-Saving Irrigation Technologies

Most farmer households (particularly farmer households in Binh Phuoc) did not consider this measure the most important (Table 7.2). Only 9.6 per cent of the farmer households in the sample used water-saving irrigation technologies (Appendix 1). This is explained in Section 6.5.2 by poor access to irrigation facilities because of sloped land topography in Binh Phuoc and Dong Nai (Table 6.6) and poor availability of electricity on farms (Appendix 1).

Irrigation affects latex yield and rubber tree growth through supplementing soil moisture and lengthening growth periods (Adesina & Chianu, 2002; Baethgen et al., 2003; Kurukulasuriya &

Mendelsohn, 2007a; Kurukulasuriya & Rosenthal, 2003; Priyadarshan, 2003; Rodrigo et al., 2009; Smithers & Blay-Palmer, 2001). The use of irrigation systems can also reduce the length of immature stages (Perera & Seneviratne, 2009). Irrigation has played a crucial role in adaptation to climatic conditions (Mainuddin & Kirby, 2009; Perera & Seneviratne, 2009). Advances in irrigation technologies have made efficient irrigation possible, but irrigation efficiency in developing countries has been extremely low (Downing et al., 1997; Kurukulasuriya & Rosenthal, 2003).

Recently, spray and drip irrigation systems have been introduced to rubber growers. These technologies provide the best water-saving irrigation available. These systems can distribute both water and fertiliser to feed rubber trees, thus stimulating root growth to help absorb water and fertiliser quickly. The two experts in the local rubber industry who were consulted estimated that latex quality could be improved from 35 degrees to 38 degrees using these technologies, but that latex yield was unlikely to increase. Irrigation involves a high cost of adoption.

In Table 7.3, no farmer households in the sample considered attribute 3 (resistance to plant disease), attribute 7 (property rights), attribute 8 (application of knowledge), attribute 9 (institutional support) and attribute 11 (early returns) important against adaptive measure 4 (water-saving irrigation technologies).

7.2.5 Applying Water Conservation Techniques

Farmer households in the study area did not consider this method the most important (3.3 per cent) (Table 7.2). Water conservation practices influence the growth and potential yield of rubber trees and have played a crucial role in agricultural production and adaptation to climatic conditions (Mainuddin & Kirby, 2009; Perera & Seneviratne, 2009); for example, planting under contours, establishing stone terraces, water harvest by using drains and silt pits along the contours at row-middle ways. The methods recommended not only conserve water but also reduce weed growth and weed-related yield losses (Greenland, 1997; Purnamasari et al., 2002; Samarappuli & Wijesuriya, 2009) as well as reducing the length of immature stages (Perera & Seneviratne, 2009).

Before reaching the ground, precipitation is partly lost by run-off of surface water and absorption into rubber leaves' tissues. Surface water run-off can cause soil erosion resulting in severe depletion of essential nutrients and organic matter from the topsoil. Contour planting design helps keep rainwater for longer periods on the soil surface and diminishes run-off, which increase the infiltration of rainwater into the soil (Samarappuli & Wijesuriya, 2009). This practice is suitable on hilly and sloped terrains, but it requires minimum disturbance between planting rows.

In Table 7.3, no farmer households in the sample considered attribute 3 (resistance to plant disease), attribute 8 (application of knowledge) and attribute 11 (early returns) important against adaptive measure 5 (water conservation techniques).

7.2.6 Applying Soil Conservation Techniques

Farmer households in the study area also did not consider this method the most important (1.9 per cent) (Table 7.2). Soil conservation influences the growth and potential yield of rubber trees as well as reducing weed growth and weed-related yield losses (Greenland, 1997; Purnamasari et al., 2002). Soil conservation practices have played a crucial role in agricultural production and adaptation to climatic conditions (Mainuddin & Kirby, 2009; Perera & Seneviratne, 2009). A range of agronomic practices for soil conservation exist, including intercropping, weed control, burning crop residue, water drainage and soil amendment, drains, silt pits, stone terraces, mulching, and boundaries (Samarappuli & Wijesuriya, 2009; Wijesuriya & Thattil, 2005). These contribute to soil conservation through various direct and indirect mechanisms.

Cover crops (such as growing legumes[65] that enrich soil nitrogen) absorb surface water and reduce evaporation from soil, contributing to conservation of soil moisture and enhancing soil fertility, hence providing additional income to households (Barlow & Muharminto, 1982; Nugawela, 2008b; Senevirathna et al., 2010; Wibawa et al., 1997). Cover crop establishment helps soil and moisture conservation through adding organic matter to the soil from natural decay of leaves, stems and roots. It also avoids the direct impact of raindrops that can break down the soil texture. Each cover crop has different moisture storage capacity and requires certain soil and irrigation conditions (Mendelsohn & Seo, 2007). Cover crops coincide with a decrease in weeding costs (Nugawela, 2008b; Senevirathna et al., 2010) and a limitation of wild grass development. This is important because wild grass is a source of harmful diseases and pests.

Design of drains and silt pits along the contours minimises surface soil erosion. They function as effective water trappers from surface run-off and through fall. Stone terraces can be used on rocky ground where drains and silt pits cannot be used (Samarappuli & Wijesuriya, 2009).

Mulching provides cushion layers against the direct soil erosion of raindrops, it minimises water run-off and increases water infiltration rate in the soil. Mulching also reduces the evaporation rate of soil moisture and decreases weed growth around rubber trees (Samarappuli & Wijesuriya, 2009).

[65] For example, rubber farmers planted *kuzdu* as a cover crop.

In Table 7.3, no farmer households in the sample considered attribute 3 (resistance to plant disease), attribute 8 (application of knowledge), attribute 9 (institutional support) and attribute 11 (early returns) important against adaptive measure 6 (soil conservation techniques).

7.2.7 Employing Rain Guard Technology

This technology was preferred by farmer households in Binh Phuoc (33.6 per cent) and Tay Ninh (30.0 per cent), but was less preferred in Dong Nai (only 7.1 per cent) (Table 7.2). Rubber farmers are usually concerned about delays and losses of latex yield due to the interference of rain on tapping. Rubber farmers have to adapt to rainy weather and ensure enough tapping days (Barlow & Muharminto, 1982; Nugawela, 2008a). To avoid these losses in wet seasons, the most appropriate method is adoption of rain guard technology, which helps reduce the number of lost tapping days: from 140 to 100 days per annum in some areas in India (Nugawela, 2008a; Wijesuriya & Dissanayake, 2009). "Since a rubber tree is generally tapped every other day this will mean that each tree will get 50 additional tapping days due to rain guarding" (Nugawela, 2008a, p. 42). Rain guard adoption requires skilled tappers to ensure technical efficiency and market availability of specialised utensils such as rain guard sealant (Nugawela, 2008a). However, rain guard technology is expensive to adopt.

Although the adoption of rain guard technology is popular, the use of this technology by rubber farmer households is still low. Normally, it takes tappers slightly more time per rain-guarded rubber tree to perform the tapping. This can make hired tappers reluctant and landowners may need to encourage them by paying a bonus for tapping in such periods. Rubber farmer households themselves may create a profitable condition for tappers to perform their duties better. Lack of efforts by both landowners and tappers also affects the adoption of this adaptive measure (Nugawela, 2008a, 2009).

In Table 7.3, no farmer households in the sample considered attribute 3 (resistance to plant disease), attribute 7 (property rights) and attribute 11 (early returns) important against adaptive measure 7 (rain guard technology).

7.2.8 Applying Correct Tapping Techniques

Many farmer households in all the three provinces preferred this method (Table 7.2). Latex yield depends on a range of factors cited in Section 6.2. According to Wijesuriya et al. (2007), the tapping time which ensures the best latex extraction is dependent on temperature. Late tapping may cause a 25-per cent loss of latex production in comparison with normal tapping (Nugawela, 2008a). Over-tapping and over-stimulation of latex growth may help rubber farmer households maximise current profit, but this affects subsequently latex yield and rubber tree quality over time (Wijesuriya et al., 2011). This method can also decrease DRC levels in latex, but frequent tapping with low stimulation can increase DRC levels (Nugawela, 2006).

If tapping occurs during rain, then panel diseases can result and latex quality can decrease. Latex production may also be lost if the tapping panel is wet allowing latex to flow out of the tapping cut (Nugawela, 2008b). Therefore, the tapping position and latex collecting cups need to be covered by rain guards fixed on the bark. Tapping position protection is very important and requires strict management. A thicker cutting for tapping may not result in a high yield and will decrease the number of possible tapping years (Nugawela, 2008b).

Tapping skills, tapping schedules and latex storage tools help rubber farmer households maximise latex yield and quality without affecting the post-harvest rubber plant development. Tapping techniques such as the correct angle of the tapping cut (30 degrees from the horizontal plane to maximise latex removal), thickness of the cut, correct height of the tapping panel (120 cm from the base of rubber trees), correct direction of the tapping cut, and correct length of the tapping cut may ensure a high latex yield (Wijesuriya et al., 2007).

In Table 7.3, no farmer households in the sample considered attribute 3 (resistance to plant disease), attribute 7 (property rights) and attribute 11 (early returns) important against adaptive measure 8 (correct tapping technique).

To sum up, the three adaptive measures considered most preferred in the sample were (1) proper rubber clones, planting materials and sound crop establishment, (2) rain guard technology and (3) correct tapping techniques. Most rubber farmers believed that a combination of these measures would improve latex quality and yield (average increase in latex yield about 19 per cent if the combinations were adopted) (Appendix 1). Higher yield and quality of latex results in more secure incomes under changing climatic conditions.

7.3 Constraints to Adaptation

Understanding constraints to adoption is relevant to formulating successful policy responses (Charles & Rashid, 2007; Smit et al., 2001). According to Ongley (1996) and Sarker (2012) that target the practical needs of farmer communities.

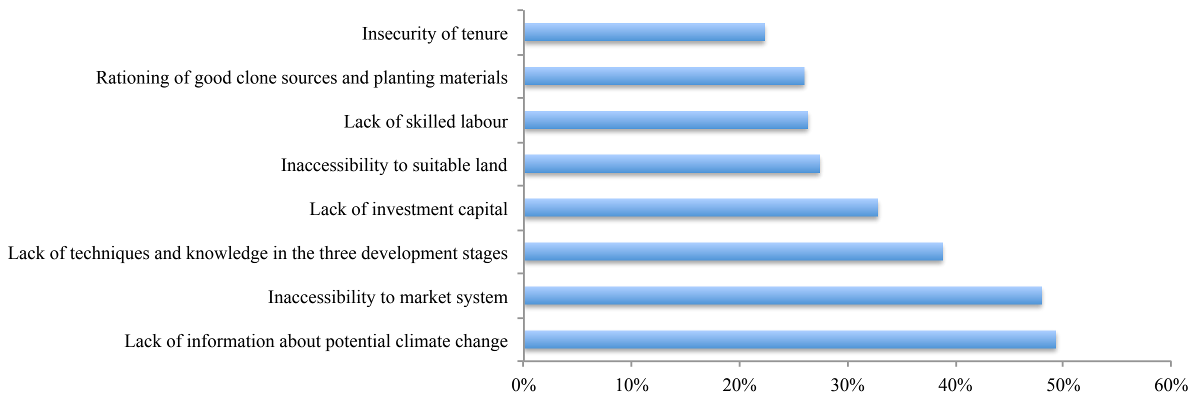

Figure 7.1: Main constraints to adoption of adaptive measures in the study area

Source: Estimates using the survey data

Rubber farmer households could either experience difficulties when applying adaptive measures or be constrained by various aspects. The farmer households in the sample identified the following main constraints (Figure 7.1): lack of information about potential climate change (49.3 per cent), inaccessibility to the market system (48.0 per cent), lack of techniques and knowledge in planting, nursing and harvesting stages (38.8 per cent), lack of investment capital (32.8 per cent), inaccessibility to suitable land (27.4 per cent), lack of skilled labour (26.3 per cent), rationing of good clone sources and planting materials (26.0 per cent), and insecurity of land-use rights (22.3 per cent). Almost all small-scale farmer households are operating under such resource limitations, which limits their ability to get the necessary resources for adaptation (Charles & Rashid, 2007).

According to the FAO (undated), there were seven important crop constraints for the rubber industry in Vietnam which also emphasised water shortage, labour shortage, poor water access and rationing of technical support, credit and market arrangements. Farm householders in Southeast Vietnam (Figure 7.2) also emphasised their disadvantages in terms of lack of investment capital (over 60 per cent), lack of scientific and technical knowledge (over 50 per cent), lack of information on markets (about 30 per cent), lack of production support services (nearly 30 per cent), difficulty in selling products (about 22 per cent), lack of labour (over 20 per cent), lack of productive land (nearly 17 per cent) and lack of good breeds and varieties (about 15 per cent) (GSO, 2012).

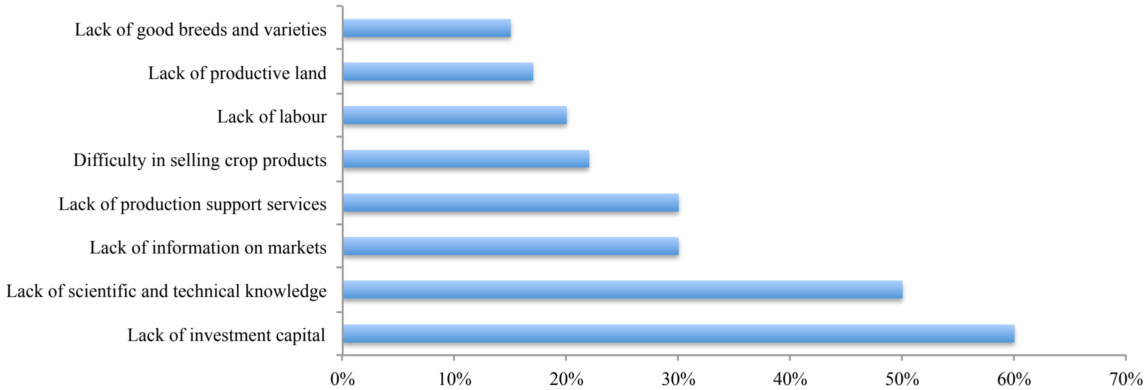

Figure 7.2: Main constraints in agricultural production in Southeast Vietnam

Source: Estimated using data sourced from the GSO (2012)

The farmer households in the survey of the GSO (2012) expressed solutions that would assist them, including assistance with bank interest rates (about 63 per cent), support with science and technology in producing and processing products (about 55 per cent), selling crop products (about 36 per cent), training on management knowledge (about 31 per cent), support with good breeds and varieties (about 31 per cent) and security of land-use rights (about 20 per cent) (Figure 7.3).

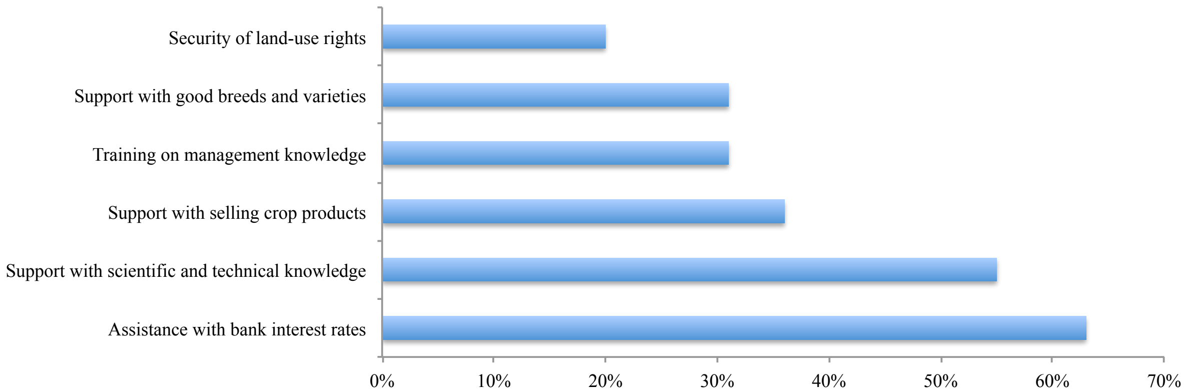

Figure 7.3: Solutions suggested by farmers to overcome constraints in agricultural production

Source: Estimated using data sourced from the GSO (2012)

Only 9.2 per cent of the farmer households expected to switch from rubber production to other crops for better income (Appendix 1). The tendency of farmer households to adopt other crops and other land-use types for better income is important information, indicating the sustainability of the system that addresses the value of rubber cultivation as a forest cover (Wijesuriya et al., 2007). Fast changes in prices of perennial crops such as cocoa and black pepper have affected farmer households' decisions to remain or abandon other perennial crops (Liu et al., 2007). The types of land they own may affect rubber farmer households' decisions on using land (Wijesuriya et al., 2011). If a region experiences a long and rich tradition of planting a particular crop, the transition from this crop to a newer and more suitable crop can be difficult (Kurukulasuriya & Rosenthal, 2003).

7.4 Discussion and Conclusion

The agro-ecological setting, consisting of climate, edaphic condition and land topography, is important in natural rubber production. These are comparative advantages in Southeast Vietnam compared with other regions of the country. Rural infrastructure, institutions and socio-economic conditions presented in Chapter 6 create opportunities for farmer households to access markets for agricultural inputs and outputs, security of tenure, extension services, credit and so on. A thriving period before the year 2010 created economic incentives to further expand rubber cultivation over the country.

However, many farmer households in the sample considered inaccessibility to the market system as a key constraint. This results some households receiving lower latex prices than others would be possible. The vast majority of rubber farm households derive their main income from agricultural activities. Farmer households need advanced credit from local traders as their main source of capital.

Most rubber farmers have good perceptions of changes in the main climate variables in the study area. They adapt to such changes through choosing combinations of adaptive measures of which improved irrigation was not a priority. The role of television was important in farm communities as a source of information on agricultural recommendations, climate and weather. Nonetheless, many rubber farmers still lacked information about potential climate change and that constrained their adoption of adaptive measures.

Most rubber farmers received training on planting, nursing rubber trees and tapping for latex. They also engaged in local social commitments. Education shows advantages in terms of having other occupations, participating in social commitments and using skilled labour. Females do not show disadvantages in earning non-farm income compared with males. However, many of farmer households still complained of lack of skilled labour and lack of techniques and knowledge in the three development stages of rubber trees, which constrained them from adopting the desired adaptive measures. Younger generations are considered an available workforce, but prefer other occupations to rubber.

Although latex yields at the farm level had statistical differences across the three provinces, latex yields at the provincial level had no statistical difference. Latex yield increases were accompanied with increases in net profit. High variability in latex yield was partly because of the use of less-improved clones. Fertiliser use is an important component contributing to increasing input expenditures, but fertiliser application was not measured and strictly controlled by farmers in the sample. Old clones need to be replaced by better new clones but rationing of good clone sources and planting materials was also a key constraint. The inverse relationship between clone sources from state nurseries and latex yield was a surprising finding. This requires further study on distribution of clones and how farmers obtain clones from state nurseries in the study area.

Although most farm households obtained certificates of land-use rights, there were concerns of insecurity of tenure and inaccessibility to suitable land. These may be effects of urbanisation in the most dynamic economic region of the country. Interestingly, only very few rubber farmers expected to switch from rubber production to other crops for better income.

Adaptive measures most preferred were use of: (1) proper rubber clones, planting materials and sound crop establishment, (2) rain guard technology and (3) correct tapping techniques. These results have interesting policy implications. More in-depth analyses in Chapter 8 indicate reasons farmer households choose the combinations above and the determinants of their choice behaviours.

Chapter 8 Heterogeneous Preferences for Adaptive Measures at Farmer-Segment Level and Adaptation Determinants: Econometric Analyses Using the Survey Data

8.1 Introduction

This chapter addresses the three issues cited in research questions 7, 8 and 9: (i) adaptive measures to changing climatic conditions, underlying attributes of adaptive measures being practised; (ii) reasons farmer households choose different adaptive measures and combinations, adaptive behaviour types of farmer segments; and (iii) the determinants of their choice behaviour. Econometric models of reliability analysis, factor analysis and the LCM are used to understand correlations among these three issues from statements of rubber farmer households who use adaptive measures.

This chapter analyses the reliability of measuring discrete attributes across the respondents. Farmer preferences are considered to be latent variables and are heterogeneous, because adaptation at the farm level is inconsistent (Kurukulasuriya & Rosenthal, 2003; Yu et al., 2013). Preference for a particular adaptive measure cannot be measured directly by one question. Therefore, indirect measurement through their attributes must be applied. A reliability analysis model identifies a reduced set of underlying attributes among a full 14-adaptive attribute set which can explain best the choice behaviour of farmer households among these 14 attributes. Underlying attributes have the strongest correlations of agreement scores to every adaptive measure across the respondents but also across the attributes. These attributes are differentiated from others with weaker correlations thereby underlying attributes are grouped together.

The choice behaviour can be more easily understood when a factor analysis model is used to classify these reduced attributes into several finite groups, also either reduce the number of variables in analyses or detect relationships among variables. Factor analysis helps identify underlying attributes that can differentiate adaptive preferences across the respondents. Some underlying attributes that have weak explanatory power in differentiating adaptive preferences across the respondents are dropped from factor analysis. The number of finite groups is usually fewer than the number of included attributes. Each group contains one or some of the underlying attributes, and is representative of a behaviour type of a farmer household. Each final factor, after a rotated procedure, is estimated to consist of the only underlying attribute(s). Different final factors consist of different underlying attribute(s). The goal of this procedure is to provide meaningful descriptions of the factors.

The LCM estimates the utility of final factors among segments, and the determinants of behaviour types among segments. It analyses the probability of a given farmer household belonging to a segment that has homogeneous preference of different groups for underlying attributes. Based on these probabilities, the LCM helps group rubber farmer households with similarity of household-specific and site-specific characteristics into one segment. Findings from the survey data were used to draw implications for policy-making. Policy responses in Chapter 9 focus on these segments of rubber farmer households, segment-specific adaptive preferences and segment-specific characteristics in order to obtain their efficacy of policies in practice.

This chapter is organised as follows. Section 8.2 analyses the reliability of measuring discrete attributes across the respondents. The method of reliability analysis is also applied to assess opinions of the farmer households in the survey about the local supply of agricultural inputs to complement information in Chapter 6. Factor analysis helps identify underlying attributes that can differentiate adaptive preferences across the respondents best. The LCM addresses other main findings of the study. Section 8.3 discusses and concludes this chapter.

8.2 Model Analyses

8.2.1 Reliability Analysis of the Explanatory Power among Adaptive Attributes

A reliability analysis model was used to test the quality of the 5-point Likert measurement of the 14 attributes. Results of the analysis show a *Cronbach's alpha of the full model* of 0.71 with 10 attributes included in the model (Table 8.1). For these 10 attributes a *Cronbach's alpha if attribute deleted* is less than 0.71 indicating these 10 attributes contribute to the measurement of farmer preferences for adaptive actions. The remaining four attributes are excluded from further analyses, because their inclusion does not improve the explanatory power of the model (Hoang & Chu, 2005).

Table 8.1: Reliability analysis of the explanatory power among adaptive attributes

No.	ID	Short-cut attributes	Cronbach's alpha if attribute deleted
		Cronbach's alpha of full model	**0.71**
1	1	Resistance to drought	0.68
2	2	Resistance to heavy winds	0.68
3	4	Skilled labour availability	0.69
4	5	Capital availability	0.66
5	6	Time availability	0.69
6	7	Property rights	0.70
7	8	Application of knowledge	0.69
8	10	Market access	0.67
9	11	Early yields	0.71
10	14	Technical and economic efficiency	0.71

Source: Estimates using the survey data

The four attributes excluded are (i) resistance to plant diseases (attribute 3), (ii) availability of institutional support (attribute 9), (iii) higher yield (attribute 12) and (iv) better latex quality (attribute 13). The choice of adaptive measures does not seem to be strongly decided by these four attributes, because their explanatory power in the model is weaker than for other attributes. In Table 7.3, about 29.8 per cent of the farmer households in the sample placed *attribute 3* with high significance on *adaptive measure 2*. Less than 10 per cent of the farmer households in the sample placed *attribute 9* with high significance on *adaptive measures 2* and *8*. About a third of the farmer households in the sample considered *attributes 12* and *13* of similar significance on all the adaptive measures on which they focus on *adaptive measures 2*, *7* and *8*. Although these four attributes show high importance among *adaptive measures 2*, *7* and *8*, their exclusion in the model relies on farmer preferences across point intervals of different agreement levels.

To deal with the changing climatic conditions, rubber farmer households tended to rely on these 10 attributes. About a third of the farmer households in the sample considered *attributes 1* (drought resistance), *2* (heavy-wind resistance), *4* (skilled labour availability) and *14* (technical and economic efficiency) with similar significance on *adaptive measures 2*, *7* and *8*.

Less than 20 per cent of the farmer households in the sample also considered *attributes 5* (investment capital availability), *6* (time availability), *8* (application of technological and knowledge) and *10* (market access of inputs and services) of similar significance on *adaptive measures 2*, *7* and *8*.

They considered *attributes 7* (property rights) and *11* (early yields) of high significance on *adaptive measure 2*.

8.2.2 Factor Analysis for Formulating Farmers' Adaptive Responses

A factor analysis model was applied to the 10 attributes in Table 8.1, and results are presented in Table 8.2. Table 8.2 presents a summary of the factor analysis of attitudinal statements of attributes reflecting farmer households' motivations for adaptation to climate change in the rubber farming system in Southeast Vietnam, using a rotated component matrix. Three statistical indicators show that this model is statistically significant: the KMO test (0.65), the approximate Chi-squared value of the Bartlett test (1403, $p < 0.05$) and the cumulative value (68.99). This model classifies farmer preferences into four behaviour types (factors), selecting four initial eigenvalues greater than one. These four factors explain about 69 per cent of variation of the dataset in this model. A rotated component matrix shows the seven further reduced attributes with high loading values (greater than 0.7) in each relevant factor (Table 8.2). The three attributes of land-use rights (attribute 7), application of techniques and knowledge (attribute 8) and market access (attribute 10) are excluded in this model. These three attributes are important in the previous reliability analysis, but are not statistically significant in distinguishing the four behaviour types of the farmer households in the sample.

Table 8.2: Summary of the factor analysis using a rotated component matrix

No.	ID	Statement of attributes	Factor loadings			
			Factor 1	Factor 2	Factor 3	Factor 4
1	1	Resistance to drought		0.95		
2	2	Resistance to heavy winds		0.95		
3	4	Skilled labour availability	0.71			
4	5	Capital availability	0.75			
5	6	Time availability	0.73			
6	11	Early yields				0.83
7	14	Technical and economic efficiency			0.86	
		KMO	**0.65**			
		Bartlett's approx. Chi-squared	**1403***			
		Cumulative percentage	**68.99**			

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

The factor 1 group is concerned with adaptive measures where farmers may obtain three attributes of availability of (i) skilled labour, (ii) investment capital and (iii) suitable time to conduct tasks. These attributes are related to availability of economic inputs such as capital and labour. Therefore, this group is named *resource attributes*. This group is willing to adopt adaptive measures when essential financial and labour resources are available. Farmers are assumed be under resource limitations and be risk averse. They are usually looking for additional income from non-farm activities to improve their income, so their time allocation to farming activities is also limited. Especially the young workforce has a propensity to prefer other occupations rather than farming, while poorly resourced farm households have a propensity to use more family labour. Local availability of skilled labour for rubber farming shows a limitation (Chapter 6). Farmer households have need of official loans and advance payments by local traders, so local unavailability of investment capital also is a constraint. Loans and advance payments may make farmers get into debt due to poor harvests, so that they have less incentive to ask for loans. Availability of such resources facilitates adoption by poor farm households.

The factor 2 group is concerned with adaptive measures which improve two attributes (i) drought resistance and (ii) heavy-wind resistance. These attributes are related to clonal technologies and methods that diminish negative impacts of drought and heavy winds on rubber trees. Therefore, this group is named *biological attributes*. This group expects to deal with forecasted climate risks such as high temperature and heavy wind. Farmers concurred that local weather and climate status had been changing over time, with high temperatures and heavy winds exhibiting increasing trends. Farmers also concurred that losses in latex yield and quality occurred because of such climate events.

The factor 3 group is concerned with adaptive measures which ensure technical and economic efficiency of the adoption in natural rubber production. Therefore, this group is named *efficient attributes*. Farmers are assumed to be profit maximisers, so they will need to operate at the economic optimum rather than at the technical optimum. Poorly resourced farmer households need to avoid downside risks from adoption of practices, so they may put high significance on technical and economic efficiency. Such efficiency helps farmer households diminish economic pressures from losses in yield.

The factor 4 group is concerned with adaptive measures which affect the harvest timing. This group concentrates on obtaining early yields/income and it is related to quick economic returns. Early income from early harvest may help rubber farmer households obtain capital to pay expenses. Many farmers in the sample felt uncertainty of latex prices and market arrangements, so this attribute is considered as a proxy for returns. This action requires, for example, applying latex stimulants on tapping panels. It also relates to risks that can occur in the long-term. Therefore, this group is named *early return attributes*.

These four groups cover the farming behaviour of rubber farmer households and are clearly differentiated, using estimates from the survey data. Farmers in general tend to be risk averse (Dillon & Hardaker, 1980; McConnell et al., 1997). According to Purnamasari et al. (2002), rubber farmers, who are risk averse, prefer lower planting density, longer rotation length and later tapping. Behaviour groups 1, 2 and 3 seem to be risk averse, while behaviour group 4 seems to be less risk averse. Because behaviour group 4 is willing to accept early yields.

Behaviour groups 1 and 2 seem to be driven by risk minimisation in terms of climate impacts and resource allocations, while behaviour groups 3 and 4 seem to be driven by profit maximisation in the long-term and short-term. Also behaviour group 1 looks to achieve input efficiency, while behaviour groups 2, 3 and 4 are more concerned with output efficiency. These behaviour groups can constrain efficient adaptation at the farm level when adaptive measures or policy responses ignore households' particular preferences. Exploiting knowledge of site-specific and household-specific characteristics within segments is useful to align policy responses that promote successful adaptation at the farm level.

8.2.3 Determinants of Farmer Segments' Adaptive Responses

The analytical basis of the LCM helps in corporating three domains of rubber farmer households' choices among adaptive measures, their preferences for adaptive attributes, and their household-specific characteristics to estimate the probability of a given rubber farmer household belonging to a particular segment. Observed features and directly unobserved variables of the farm households were used in these analyses. Observed features cover institutional factors, socio-economic factors, agro-environment characteristics, demographic and farm characteristics. Unobserved variables included farmer preference for the adaptive attributes, because only the combinations of the adaptive measures were observed.

This study applied the stated choice method, using the survey data from the choice experiments on farmer households' adaptive responses to climate change in Southeast Vietnam. The choice experiment consisted of 6 below choice sets among 8 adaptive measures in the three development stages of rubber trees, and each choice set included 14 attributes with 5 relevant satisfaction levels. Basically, the LCM simultaneously groups farmer households into relatively homogeneous segments and explains adaptive responses of segment members.

Table 8.3: Combinations among the adaptive measures in the sample

Y	**Combinations**
Option 1	If a household chooses only adaptive measure(s) in the planting stage
Option 2	If a household chooses only adaptive measure(s) in the harvesting stage
Option 3	If a household chooses only adaptive measure(s) in the planting and nursing stages
Option 4	If a household chooses only adaptive measure(s) in the planting and harvesting stages
Option 5	If a household chooses only adaptive measure(s) in the nursing and harvesting stages
Option 6	If a household chooses adaptive measure(s) in all three stages

Source: Estimates using the survey data

Based on the survey dataset, preferred adaptive choices of the rubber farmer households are classified into six combinations (dummy variable, *Y*) among the eight adaptive measures (Table 8.3). *Y* collects the stated choice in each choice occasion and is expressed as a row vector containing five zeros and a one. A combination of adaptive measures is meaningful in practice. This has the potential to considerably decrease the magnitude of adverse climate impacts on agricultural production, or to enhance beneficial climate impacts (Bradshaw et al., 2004; Charles & Rashid, 2007; Kurukulasuriya & Rosenthal, 2003; Lasco et al., 2011; Wijesuriya et al., 2011; Wijesuriya & Thattil, 2005). The assumption of the combination is based on a point of view that farmer households face resource limitations. Limited-resource farmer households would have propensity to prefer some adaptive measures over others, because those adaptive measures address desirable attributes and are feasible within the constraints farmers face.

There is no option for only nursing stage, because the survey dataset does not show this. The nursery is important to improve the quality of plantations and trees, but itself may be not efficient enough to deal with climate change and variability. Therefore, this does not mean that the farmer households in the sample have omitted this choice. Only four rubber farm households chose the "null" option (no adaptation).

Table 8.4: Summary of the converged latent segment models

Segments	LLF	*Nparam*	CAIC	BIC
2	-645.01	19	1424.23	1405.23
3	**-349.21**	**34**	**938.59**	**904.59**
4	-308.59	49	963.30	914.30
5	-258.04	64	968.16	904.14
6	-373.76	79	1305.55	1226.55
7	-289.02	94	1242.05	1148.05
8	-285.47	109	1340.90	1231.90
9	-325.46	124	1526.83	1402.83
10	-215.67	139	1413.20	1274.20

Source: Estimates using the survey data

There were 430 rubber farm households who formed the four adaptive behaviour types created from the factor model. Whether there are finite farmer segments who have within-segment homogeneous preferences for these adaptive behaviour types is an empirical question for policy-making. This section shows how to answer this question when farmer preferences are directly unobserved. The number of segments is endogenous, so there is no prior information on the appropriate number of segments. It is recommended that the researcher choose the statistically optimal number of segments, commonly based on measures of fit and information criteria such as BIC or CAIC (Sagebiel, 2011). Both BIC and CAIC are minimised with three segments (Table 8.4), so this econometric analysis suggests that three segments of farmer households exist in the sample. The magnitude of BIC and CAIC values is the smallest at the 3-segment level. There are 34 parameters in this 3-segment LCM model. According to Sagebiel (2011), a three-class choice model has a reasonable fit.

According to Pacifico and Yoo (2013), how well the model does in differentiating finite segments of choices is obtained by checking the highest posterior probability of segment membership (Table 8.5).

Table 8.5: Summary of the overall goodness of fit of the LCM

Segment	N	Average unconditional probability	Average conditional probability	Mean highest posterior probability			
				Mean	SD	Min	Max
1	177	0.53	0.99				
2	115	0.44	0.67				
3	138	0.47	0.97				
	430			0.78	0.17	0.38	1.00

Source: Estimates using the survey data

In Table 8.5, the mean highest posterior probability is > 0.5 (0.78). This means the model does well in distinguishing among different underlying taste patterns for the stated choice behaviour. The average unconditional choice probability is > 0.25 in all alternatives, indicating a suitable model. It could predict segment membership given that there are two alternative segments per choice occasion. The average conditional choice probability is > 0.5 in all alternatives. The above statistical indicators show that the model could describe the stated choice behaviour well (Pacifico & Yoo, 2013). According to Sagebiel (2011), the overall model is statistically significant and this suggests heterogeneity in farmer-segment preferences.

The relative size of each segment is estimated in Table 8.5. The segment membership model estimates 177 rubber farmer households have the highest probability belonging to segment 1 (41.2 per cent), 115 rubber farmer households have the highest probability belonging to segment 2 (26.7 per cent), 138 rubber farmer households have the highest probability belonging to segment 3 (32.1 per cent). Based on the highest probability score, this procedure creates a series of probabilities to distinguish a given farm household within three segments. Farm households are distributed repeatedly into a segment; this procedure is stopped until convergence has been obtained.

The two models in Table 8.6 estimate 34 parameters within the three segments of rubber farm households. Section I shows 12 parameters of the choice model regarding adaptive responses, and Section II shows 22 parameters of the segment membership model regarding site-specific and household-specific characteristics. Segment 3 contains zero-loading values, because segment 3 is a reference segment. The parameters of this segment in Section II are normalised to zeros in order to estimate the remaining parameters of the segment membership model. The parameters have the same signs in segments 1 and 2 implying that the related determinant belongs to the reference segment (Birol et al., 2007; Boxall & Adamowicz, 2002).

Table 8.6: Parameters of the choice model and the three-segment model

No.	Variables (N = 430)	Segment 1	Segment 2	Segment 3
I	**Choice model: adaptive attributes**			
1	Resource attributes	-11.54	0.99	**13.39**
2	Biological attributes	**10.40**	0.44	-35.46
3	Efficient attributes	-5.34	**2.30**	-33.01
4	Early return attributes	-39.14	1.09	**24.42**
II	**Segment membership model: site and household-specific characteristics**			
1	Obtains certificate of land-use rights (No=0, Yes=1)	0.805	0.569	0
2	Has participated in farmer groups (No=0, Yes=1)	0.385	0.289	0
3	Hires labour (No=0, Yes=1)	0.987	0.360	0
4	Has convenient access to irrigation facilities (No=0, Yes=1)	0.238	0.323	0
5	Net profit per ha	0.004	-0.016	0
6	Rubber land size	-0.036	0.042	0
7	Years of schooling of household head	-0.053	0.052	0
8	Household size	-0.169	-0.034	0
9	Age of rubber trees	-0.070	-0.164	0
10	Chooses monoculture systems (Multi=0, Mono=1)	-0.832	-0.253	0
	*cons_*	*1.141*	*1.410*	0

Model was estimated via the expectation-maximisation (EM) algorithm.

Source: Estimates using the survey data

The choice model is associated with the seven adaptive attributes which are grouped into the four basic adaptive response types. The segment membership model is associated with the rubber farm households' profile including (i) 1 institutional factor (*Obtains certificate of land-use rights*); (ii) 4 socio-economic factors (*Has participated in farmer groups*, *Hires labour, Net profit per ha* and *Rubber land size*); (iii) 2 demographic variables (*Years of schooling of household head* and *Household size*); and (iv) 3 farm-specific variables (*Age of rubber trees*, *Has convenient access to irrigation facilities*, and *Chooses monoculture systems*). These are 10 determinants that are considered as affecting farmer households' adaptive decisions at the farm level in the study area.

(1) Profile of segment 1

Rubber farmer households in segment 1 have a propensity to prefer *biological attributes*, while they have a propensity not to prefer *efficient attributes*, *resource attributes* and *early return attributes*. *Early return attributes* are the least preferred with the highest absolute parameter value of 39.14 (Table 8.6).

The membership parameters of segment 1 indicate that higher net profit per ha increases the probability of a given farmer household belonging to this segment. Farmer households with larger farms are less likely to belong to this segment. Similarly, farmers with higher years of schooling are less likely to belong to this segment. In Chapter 6, rubber land sizes and education levels (years of schooling) have no significant correlations with net profit per ha. The parameters of land size and years of schooling, which equal -0.036 and -0.053 respectively, have absolute values greater than the parameter of net profit per ha (0.004), indicating the particular significance of these two variables compared with net profit. Farmer households in this segment are thus considered as having low endowments of land size and education level (poor resources), *biological attributes* could increase their utility. Net profit increase (better efficiency of production) is associated with a higher propensity to invest in this adaptive method.

These findings can be explained by assumptions that limited-resource farmer households focus on avoiding destruction of their rubber trees by extreme weather events (drought and heavy winds). Thereby *biological attributes* increase their utility. This ensures their income flow from rubber latex is stable over time, since most poor farmers place a higher value on risk minimisation rather than on profit maximisation (Dung, 2007; Wibawa et al., 2006). These farmer households would not look for profit and available-resource targets, because they might lack more opportunities of land size and education level to invest in these businesses. Therefore, attributes such as *resource*, *efficiency* and *early return* do not increase their utility. In other words, rubber farmer households who have low endowments of land size and education level seem to have preferences for *biological attributes* holding all other variables constant. When their rubber-farm income (including income from harvest of latex, other cash crops and bees/poultry) increases, they seem to have preferences for *biological attributes* holding all other variables constant.

(2) Profile of segment 2

Rubber farmer households in segment 2 have a propensity to prefer all four attribute groups (Table 8.6), but *efficient attributes* impact the most strongly on their utility with a parameter of 2.3 representing the largest value. In contrast with segment 1, lower net profit per ha (poor efficiency of production) increases the probability of a given rubber farmer household belonging to this segment. Farmer households with larger farms are more likely to belong to this segment. Similarly, farmer households with higher years of schooling are more likely to belong to this segment. The parameters of land size and years of schooling, which equal 0.042 and 0.052 respectively, have greater values than the parameter of net profit per ha (0.016). These indicators indicate the particular significance of these two variables compared with net profit.

Rubber farmer households in this segment are thus considered very ambitious to obtain all of the attributes. These households appear to face a trade-off between risk minimisation and profit maximisation. They have better endowments of land size and education level (better resources), and *efficient attributes* increase their utility most, holding all other variables constant. Low on-farm income (low net profit) is also a proxy of technical and economic efficiency.

These findings can be explained by the fact that farmer households with large land size and more years of schooling have a greater possibility of benefiting from scale economics, and thus they would seek and achieve higher profits. However, if their on-rubber farm income is low, their preferences are for *efficient attributes* holding all other variables constant. Therefore, attributes of *efficiency*, *early return* and *resource* increase their utility most. *Biological attributes* are also preferred but not to the same degree.

(3) Profile of segment 3

Rubber farmer households in segment 3 have a propensity to prefer *early return attributes* and *resource attributes*, while they have a propensity not to prefer *biological attributes* and *efficient attributes*. *Early return attributes* are most preferred with the highest parameter value of 24.42, while *biological attributes* are least preferred with the highest absolute parameter value of 35.46.

All above findings show that there is heterogeneity of preferences for adaptive attributes among farmer segments. *Resource attributes* and *early return attributes* are most preferred by rubber farmer households in segment 3, but are not most preferred by rubber farmer households in segment 1. In contrast to segment 3, segment 2 has the least regard for these two attributes.

A range of site-specific and household-specific characteristics might increase the probability of a given farmer household belonging to segment 3. The security of tenure, positive participation in farmer groups, hired-labour use and good access to irrigation facilities contribute to increasing the probability of becoming a member of this segment (better institutional support, positive social networks, convenient conditions of socio-economics and production). In Chapter 6, these factors create incentives for farmer households to improve on-farm income and adaptation.

Table 8.7: Distinctive characteristics of rubber farm households among three segments

No.	Description of site-specific and household-specific characteristics	Segment 1 (N = 177)	Segment 2 (N = 115)	Segment 3 (N = 138)
I	**Median**			
1	Age of rubber trees**	9	8	10
2	Household size*	4	4	4
3	Net profit per ha**	**48**	**34.5**	**48.5**
4	Rubber land size*	**3**	**2**	**3**
5	Years of schooling of household head*	8	10	10
6	Years involved in farming**	20	15	20
7	Stand density**	550	500	550
8	Latex yield per ha**	**2**	**1.67**	**2**
II	**Percentage**			
1	Has convenient access to irrigation facilities** (answered Yes)	**51.09%**	**30.57%**	18.34%
2	Have participated in farmer groups (answered Yes)	**44.54%**	**28.15%**	27.31%
3	Chooses monoculture systems** (answered Mono)	31.50%	28.74%	**39.76%**
4	Hires labour (answered Yes)	**47.06%**	25.81%	27.13%
5	Obtains certificate of land-use rights** (answered Yes)	**44.96%**	27.67%	27.38%
6	Location**			
	Binh Phuoc	*27.7%*	*18.3%*	*58.0%*
	Dong Nai	*20.3%*	*57.4%*	*27.5%*
	Tay Ninh	*52.0%*	*24.3%*	*14.5%*

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Other characteristics might decrease the probability of a given farmer household belonging to segment 3. Large household size, old rubber plantations and monoculture systems contribute to decreasing the probability of becoming a member of this segment. In Chapter 6, these two factors of old rubber plantations and monoculture systems appear to constraint farmer households from improvements in on-farm income and adaptation. Therefore, farmer households in segment 3 have better conditions for production and seem to be profit maximisers. They have a high propensity to apply methods that could help them in improving their availability of resources.

Statistical differences between farm households' profiles among the three segments highlight the above relationships. Descriptive statistics for characteristics of each segment are shown in Table 8.7. This section tests whether key factors of farm households are statistically different across the three segments. The Kruskal Wallis test and the Chi-squared test are used. The factors include age of rubber trees, household size, net profit per ha, rubber land size, years of schooling of household head, years involved in farming, stand density and latex yield per ha. Star symbols (*) show cases where the null hypothesis, that the three samples are drawn from populations with the same median, is rejected ($p < 0.05$).

(4) Summary of LCM results

Segment *1* consists of the majority of farm households in Tay Ninh (52.0 per cent). Segment *2* consists of the majority of farm households in Dong Nai (57.4 per cent), and segment *3* consists of the majority of farm households in Binh Phuoc (58.0 per cent) (Table 8.7). This distribution of farm households shows clear localisation. This is important information for designing policies and programs at the provincial level. Policies and programs would directly impact on targeted farm households located in the same province.

Segment *2* has the lowest yield (1.7 tonnes), the smallest stand density (500 rubber trees) and the smallest land size (2.0 ha) compared with segments *1* and *3*. These features contribute to the lowest net profit in this segment (34.5 million VND). This segment operates under limitations of output efficiency, economies of scale and socio-economic conditions. This segment applies popular multiculture systems. In this segment the age of rubber trees is also the lowest, so multiculture systems might be suitable. Monoculture systems are only present in 28.7 per cent. Family labour use is popular, because hiring labour is only present in 25.8 per cent (Table 8.7).

Segment *3* is likely to be the most disadvantaged group. The group has less access to irrigation, has less diverse plantations and is less connected. Unlike segments *1* and *2*, this segment shows poor access to irrigation facilities (81.7 per cent of farmers), and the lowest participation in farmer groups (27.3 per cent). About 40 per cent use monoculture systems and only 27.4 per cent attain security of tenure. Only 27.1 per cent hire labour. However, their output efficiency is quite similar to segment *1*, but is greater than segment *2* (Table 8.7). Segment *3* has higher yield (2.0 tonnes), higher stand density (550 rubber trees) and higher land size (3.0 ha) compared with segment *2*. These features contribute to higher net profit in this segment (48.0 million VND).

Finally, segment *1* has advantages in production, social networks, socio-economics and institutional support. This segment shows best access to irrigation facilities (51.1 per cent), and the highest participation in rubber farmer groups (44.5 per cent). Many of them use hired labour (47 per cent) and up to 45 per cent attain security of tenure. This segment also uses popular multiculture systems. In this segment age of rubber trees is higher than segment *2* but still low (Table 8.7). Farmers in segments *1* and *3* also have more farming experience than farmers in segment *2*. However, education level in segment 1 is the lowest (8 years).

Most characteristics are statistically different between the three segments ($p < 0.05$), excepting farmer networks and hired labour employment. The site-specific characteristics (social networks, socio-economics and institutional support); household-specific characteristics (farm size, socio-economics); output efficiency; and economies of scale capture these differences. This can explain the heterogeneity of farmer preferences for the adaptive attributes.

Segment *1* (comprising "Tay Ninh" features), which has the three advantages in production conditions, output efficiency and economies of scale, focuses mostly on *biological attributes*. Segment *2* (comprising "Dong Nai" features), which has the three disadvantages in production conditions, output efficiency and economies of scale, focuses mostly on *efficient attributes*. However, segment *2* is considered ambitious because all the four attribute types increase their utility. Segment *3* (comprising "Binh Phuoc" features), has also disadvantages in production conditions but advantages in both output efficiency and economies of scale. This segment focuses mostly on *early return attributes* and *resource attributes*. These findings presenting the adaptive behaviours of farmer segments and their segment-specific characteristics are consistent with conclusions presented in Chapters 6 and 7. Such characteristics are considered as the determinants of farmer households' adaptive responses at the farm level.

The choice model in this study shows the four adaptive response types of the three farmer segments. The heterogeneity of farmer-segment preferences for the adaptive measures is revealed. Results of the membership model indicate the determinants that influence membership of a particular segment. A local policy-maker expecting to implement any methods of adaptation should look at preferred adaptive attribute types, in order to identify the most impacted segment for the region, based on common characteristics of that segment's population.

8.2.4 Surveyed Farmers' Opinions about the Local Supply of Agricultural Inputs

The reliability analysis method was also used to identify farmer households' opinions in the survey about the local supply of agricultural inputs.

The respondents expressed their satisfaction levels with the local supply of five agricultural inputs they purchased: (i) young plants and planting materials, (ii) fertiliser, (iii) herbicide and other agrochemicals, (iv) hired labour and (v) irrigation technology. Local stores and services usually supply these inputs to rubber producers. A 4-point Likert scale was used to estimate the respondent's satisfaction level for each of the five inputs. Satisfaction was measured at four levels: *not good*, *medium*, *good* and *very good*. For each of the five inputs, the respondent chose a satisfaction level. The respondent's four answers were coded using numbers from 1 (*not good*) to 4 (*very good*). This information helps measure overall assessments of rubber farmer households regarding markets of agricultural inputs in rural areas, thereby consolidating information on markets of agricultural inputs presented in Chapter 6.

Most of the farmer households in the sample assessed the supply of agricultural inputs at medium and good levels, but 9 per cent considered the local supply of hired labour as not good, and 21 per cent considered the local supply of irrigation technologies as not good (Appendix 1). These can impact on farmer households' decisions on labour use and the adoption of irrigation technologies.

Table 8.8: Reliability analysis of the local supply among five agricultural inputs

No.	Agricultural inputs	Cronbach's alpha if item deleted
	Cronbach's alpha of full model	***0.76***
1	Young plants and planting materials	0.73
2	Fertiliser	0.68
3	Herbicide and other agrochemicals	0.71
4	Hired labour	0.73
5	Irrigation technology	0.74

Source: Estimates using the survey data

A reliability analysis model was used to test the quality of this 4-point Likert measurement. Results of the analysis show a *Cronbach's alpha of the full model* of 0.76 with the 5 inputs included in the model (Table 8.8). All the five inputs have a *Cronbach's alpha if item deleted* < 0.76; therefore, the model indicates all the five inputs can contribute to measurement of farmer households' satisfaction of the local supply of agricultural inputs.

8.3 Discussion and Conclusion

This chapter indicated firstly that there is heterogeneity of farmer preference for the eight given adaptive measures, and secondly that there are three different segments of rubber farmer households in the population. Thirdly, farmer households use combinations of adaptive measures in responding to climate change and variability, and there is mostly no adaptive deficit. Farmer households prefer seven adaptive attributes from the original set of 14. They consider *drought and heavy wind* *resistance of rubber trees*; *availability of skilled labour, capital and time*; *early yields*; *technical and economic efficiency* when deciding on adaptive methods. Four different adaptive response types are formulated, named as *biological attributes*, *resource attributes*, *early return attributes* and *efficient attributes*.

This study reveals each segment's adaptive preferences for adaptive attributes. There are 10 segment-level determinants affecting the probability of a given farmer household belonging to a segment. These segments bring together unique features of site and segment-level determinants. There is a consistency between the provincial, farm and segment level data, which is a useful finding for policy-making.

Parameters of the choice model and the segment membership model are illustrative of segment-specific preferences and segment-specific characteristics as follows. Basically, farm households who have low endowments of land and education and expect improved on-farm income have a propensity to prefer *biological attributes* (segment 1). Farm households who have better endowments of land and education but low on-farm income have a propensity to prefer *efficient attributes* most (segment 2). Farm households who have good access to tenure, social networks, irrigation facilities and skilled labour have a propensity to prefer *early return attributes* most, followed by *resource attributes* (segment 3). Large household size, old trees and monoculture system constrain this segment's adaptive responses.

Among advantages and disadvantages of the three segments, segment 1 ("Tay Ninh" features) has relative advantages (including output efficiency, economies of scale, irrigation facilities, social networks, skilled labour and security of tenure) compared with segments 2 and 3. Unsurprisingly, Tay Ninh always shows its domination of latex yield and net profit (see Chapters 6 & 7). Segment 1 prefers adaptive measures that improve the resistance of rubber trees to extreme climate and weather. This is sensible given the drier climatic conditions in Tay Ninh, as presented in Chapter 5.

Segment 3 ("Binh Phuoc" features) has similar implications to those of segment 1. However, irrigation facilities, social networks, skilled labour employment and security of tenure are identified as needing improvement in segment 3. Although Binh Phuoc also always shows its domination of latex yield and net profit (see chapters 6 & 7), its high variation of latex yield still exists. Segment 3 prefers adaptive measures that bring early returns, using available resources.

Segment 2 ("Dong Nai" features) has relative disadvantages (including output efficiency and economies of scale) compared with segments 1 and 3. Segment 2's relative disadvantages include irrigation facilities, social networks, skilled labour availability and security of tenure. Segment 2 prefers adaptive measures that improve economic and technical efficiency. This segment needs to improve their low cultivation efficiency. Chapter 9 focuses on policy implications of the segment-specific preferences for adaptive responses.

Chapter 9 Policy Implications of Climate Change Adaptation for the Small-Scale Rubber Sector in Southeast Vietnam

9.1 Introduction

As discussed in the previous chapter, a local policy-maker who expects to implement any methods of adaptation needs information on the segments most impacted by recommended methods of adaptation. This chapter helps provide local policy-makers with relevant information. However, the policy recommendations presented in this chapter are based on an extensive review of strategies, plans, policies and solutions applied to the small-scale rubber sector in Southeast Vietnam. These recommended policy responses are tailored to farmer households' adaptive responses in the study area, according to the quantitative findings in previous chapters.

The MONRE issued the national target program to respond to climate change. Its priority was coping with and adapting to climate change as key aspects of rural agricultural development. The Prime Minister of Vietnam approved the rubber development to 2015 and its orientation towards 2020. International and domestic organisations, as well as multi-level authorities of the country, were asked for their contributions to help combat climate change. Adaptive solutions for the rubber industry and support from multi-level authorities, were the key underpinning of policy recommendations.

Detailed policy responses for each farmer segment in the study area are the focus of this chapter. Policy recommendations cover three aspects of impact (spatial and temporal), application scope (local) and association scale (local governmental and individual). These aspects ensure the significance of policy responses in terms of empirical and feasible contributions.

There is widespread agreement that farm-level adaptation is crucial in coping with climate change and variability (Adger et al., 2003; Charles & Rashid, 2007; Kurukulasuriya & Rosenthal, 2003; Lasco et al., 2011; RRII, 2010; Wijesuriya et al., 2011; Yu et al., 2013). This can be a crucial choice for many poor farmers (Lasco et al., 2011), as most smallholder farmers have limited resources or low capacity to adapt to changing climatic conditions (Tazeze et al., 2012). Farm level adaptation needs appropriate policy responses to help farmer households adopt the best technologies and practices (Yu et al., 2013). Policy responses that promote strong and early actions can produce benefits far outweighing these from no action (Harris & Roach, 2007).

Rubber farmer households in the study area were aware of the adverse impacts of climate change on their rubber cultivation, production and income status. Their income vulnerability could motivate them to adapt, so their adaptive constraints needed to be removed or overcome.

Policy responses should not be considered in isolation from the local context (Ahmad et al., 2001; Alderwish & Al-Eryani, 1999; Alexandrov, 1999; Kurukulasuriya & Rosenthal, 2003; Murdiyarso, 2000). Kurukulasuriya and Rosenthal (2003) and Kirk and Tuan (2009) argue that policy responses should include solutions for poverty reduction and effective land-use at the grassroot level to enhance resilience of the poor in the agricultural sector. For example, the security of tenure contributing partly to effective land-use is an important finding of this study. Isolated solutions are necessary but not sufficient to generate incentives for agricultural productivity increases (Kirk & Tuan, 2009). They need to be considered as complementary solutions within the local context.

Adaptation strategies at the farm level presented below consider the institutional contexts, socio-economic conditions, demographic and farm characteristics within the study area. Determinants relating to these are found to be significant in the situation of interest. Policy responses thus can address the challenges of climate change and variability, as well as their potential and actual impacts on natural rubber production. These determinants are not fixed over time, so this approach requires policy responses to be dynamic. The recommended mode of rubber cultivation and production changes over time as technology evolves. This means that crop management practices are dynamic over plantation cycles (Kurukulasuriya & Rosenthal, 2003; Purnamasari et al., 2002; Reidsma et al., 2009), and so policy responses need to be updated over time, due to changes in socio-economic conditions, biophysical status of rubber trees, climate and weather patterns (Kurukulasuriya & Rosenthal, 2003).

Policy responses should focus on the preferred adaptive measure groups including (i) proper rubber clones, planting materials and sound crop establishment, (ii) rain guard technology and (iii) correct tapping techniques. Also, policy responses should concentrate on the three segments of farmer households who are interested in the four significant adaptive behaviour types (*resources*, *ecology*, *early returns*, *technical and economic efficiency*).

Farm-level policy responses are usually designed for adaptation to changes in average climatic conditions, and for adjustments to inter-annual variations and extremes. However, policy responses should be designed to deal with potential and actual impacts of climate. Although there is evidence of climate change and variability across the three provinces, differences in latex yields among the three provinces at the provincial and farm level are inconsistent. The correlation between higher increases in 5-year moving average precipitation and higher increases in latex yields are found to be statistically significant. Therefore, adapting to change and variability in precipitation brings farmer households higher levels of rubber cultivation efficiency based on the empirical evidence.

Both private and public sectors contribute to successful adaptation of farmers. Private producers consider only the benefits they can capture. Their goal may be profit maximisation, output maximisation or risk minimisation. Public benefits are also important. The presence of public benefits means that the public sector needs to get involved, to balance conflicting objectives (Ahmad et al., 2001; Charles & Rashid, 2007; Kurukulasuriya & Rosenthal, 2003; Lasco et al., 2011). Some adaptive measures have characteristics of a public good such as water-resource management for irrigation, extension services, climate and weather forecasts (Leary, 1999). These measures can operate well with state intervention (Kurukulasuriya & Rosenthal, 2003).

9.2 Groups of Policy Responses

From a policy maker's point of view, each segment of households needs its own group of solutions to boost the segment's positive characteristics and constrain its negative characteristics. These groups of solutions must be able to satisfy segment-preferred behaviour types but also consider the development of the local rubber industry, because rubber trees have a long economic life span. Preferred policy recommendations boost individual actions that improve adaptation at the farm level.

9.2.1 Solution Group of Clone Replacement

The majority of clones are less-improved old clones that should be replaced with new better clones. The average age of trees is also over 10 years, making their replacement feasible. Agricultural management agencies should assess the quantity and quality of local private clone suppliers, because they supply the vast majority of clones. Although clones from private suppliers are preferred, rationing of good clone sources and planting materials remains a concern of rubber farmer households. The government should support good clone suppliers in terms of further research and development, particularly regarding the suitability of clones to local changing climatic conditions. For instance, rubber growers need clones with high-temperature and heavy-wind resistance or clones that have a short immature stage. When new clones are widely introduced, they must be associated with the necessary supports of investment capital, skilled workforce and application knowledge. These ensure adaptation becomes consistent. Application of homogeneous selected clones is beneficial in terms of dealing with common plant diseases and facilitating the monitoring development strategies of the local rubber industry.

As most rubber plantations are in mature stages of about 10 years of age, they can be replaced. This stage is compatible with replanting or introducing new clones when the natural decrease in latex yield commences (Purnamasari et al., 2002).

The planting should be accompanied by preparation of appropriate site-slopes for drainage and preparation of irrigation conditions. These solutions should target segments 1 and 3 where their rubber trees are old enough to replace. Segment 1 is likely to be willing to adopt improved clones, while segment 2 is likely to have resource limitations to adoption. Rubber farmer households need to be equipped with technical knowledge to choose clones compatible with their farm features. Establishing compatible new clones is a strategic decision. Rubber companies in local areas are leading in the application of new clones, so their success can spillover to rubber farmers.

9.2.2 Solution Group of Family Income

Higher family income from diversification of agricultural activities is an important factor in this study. Incomes from crop cultivation and other activities improve farmer households' purchasing power of agricultural inputs and technology. Such additional income is especially useful to poor farmer households whose adaptive capacity is low in extreme weather events. Net profit depends on latex production and latex prices as well as the costs involved in producing latex. These factors also depend mostly on management decisions of farmer households. Family income can be improved through adaptive methods that help increase latex yield and decrease yield variability.

Local governments, for example, in most regions of the country are solving lack of skilled labour and redundancy of unskilled agricultural labour. High quality of a workforce helps increase family income through their work opportunities. Rubber farm households depend mainly on income sources from rubber cultivation, using mostly family labour. Net profit per ha needs to be further assessed in terms of labour productivity in the small-scale rubber sector. Most households interviewed obtained non-farm income, with no differences between genders of household head. This group should concentrate on segments 2 and 3 where farmer households need more investment for irrigation facilities and hiring labour.

9.2.3 Solution Group of Education and Training

The majority of rubber farmer households have engaged in training activities for planting and nursing rubber trees, applying fertiliser, protecting against diseases, and tapping for latex. There is a college that specialises in training technical workers for the rubber industry. The college is located in Binh Phuoc. It trains annually about one thousand workers who come from many regions of the country. Therefore, it complements the skilled workforce in the Vietnam rubber industry. Nearly half of the respondents were concerned about lack of technical knowledge regarding the three development stages of rubber trees, as well as lack of information about potential climate change.

Therefore, training activities should be allocated according to need among rubber growing regions to ensure rubber cultivation development is known widely and is conducted thoroughly. Training activity should be enhanced in terms of its quantity and quality. Climate change and climate variability issues that affect rubber trees need to be better understood and disseminated to rubber farmer households. The average education level of each household head is quite high (10 years) which facilitates disseminating knowledge and information to farmer communities.

Higher education brings advantages in terms of using labour, having other occupations or participating in social commitments. The average age of the household head is 50. Younger generations have a higher probability of obtaining non-farm income, and there is evidence that the young prefer other occupations to rubber tree growing. Therefore, the young should be educated on the potential of the rubber industry and career opportunities it brings through the whole range of cultivation, processing and export activities.

Common diseases of rubber trees exist in various localities. These should be treated simultaneously to reduce the risk of reinfection. Excessive fertiliser application was observed in this sample. This affects efficiency of resource use and plant growth. Training on fertiliser application should be enhanced, equivalent to other activities like planting, nursing rubber trees and tapping. Rubber farmer households employing skilled workers could obtain higher latex yields, but lack of skilled labour constrains them from hiring labour. Although local agricultural extension agencies hold training activities for planting, nursing rubber trees and tapping every year, the quantity of such activities only reaches several hundred participants.

9.2.4 Solution Group of Agricultural Extension

The role of agricultural extension activities is particularly significant, but information on market, agronomic recommendations, climate and weather forecasts is still considered limited by the farmer households in the sample. Some reasons commonly cited are low state budget expenditures for agricultural extension, low quality of extension services from suppliers and government officers. Only about half of the respondents were engaged with extension services and rubber farmer groups. These issues are discussed in reports of the agricultural extension industry, and efforts are being made to enhance the quantity and quality of extension. Extension activities mostly focus on: (i) providing agricultural information, (ii) training farmers and (iii) establishing good models of agricultural production to spread good practices to farmer households. Rubber farmer groups should be equipped with better knowledge and skills to adopt the methods recommended by extension services. Particularly, rubber farmer households should strictly follow a range of technical standards in the rubber industry. This ensures they are then able to compare and adjust their plantation development and product quality. Sufficient supply of a local extension workforce, and necessary facilities for these officials, will support the performance of rubber cultivation.

This solution group should concentrate on all segments, but segments 2 and 3 should receive more attention to establish local farmer networks. According to Ward and Pede (2015), technology use in agricultural production at the farm level has spillover effects within local networks where farmers usually face similar contexts of agro-ecology, culture, institutions, politics and socio-economics. Farmers within local networks may have feedback mechanisms together or direct observations of the technology use each other thereby perceiving the technology use by their own eyes rather than hearsay. Ward and Pede (2015) highlight the importance of social or peer networks on farmer behaviours. They conclude that although agricultural extension activities show important roles in helping farmer households to raise crop yield, these households' decisions about use of agricultural technologies are most influenced by practices of their peers. Farmer households particularly benefit from close peers rather than distant peers.

9.2.5 Solution Group of Tenure

Nearly all rubber farm households have certificates of land-use rights, but their adaptive measures are still constrained by inaccessibility to suitable land. Rubber plot size affects average latex yield and the farmer's adaptive capacity. The optimal size for rubber farms is not considered in this study, but the rubber land areas in the survey are ranked as small scale (commonly less than 5 ha). What should be considered is how local socio-economic development strategies and plans affect rubber farmer households' security of tenure. For example, landholders need to be informed in advance if there are plans for a transition in classification from agricultural land into homestead land or land for other strategic priorities. This ensures the farm level adaptation strategies are not disturbed in both the short term and the long term, and that policy responses enhance rubber farmer households' efficient use of a land unit. There is still the potential for increasing latex yield at the farm level. Therefore, land for rubber development should not be expanded, particularly the current expansion towards NTRAs, because Southeast Vietnam has exceeded the area approved. This solution group should concentrate on segments 2 and 3 to help them obtain certificates of land-use rights.

9.2.6 Solution Group of Resource Supply

Agricultural input costs increased associated with severely decreased output prices, creating challenges for rubber farmer households and the Vietnam rubber industry. Rubber farmer households face risks of climate change and market uncertainties. In the sample they were concerned with lack of investment capital and market inaccessibility. Only a few farmers expected to switch from their rubber plantations to other plants or land-uses. Rubber farmer households need to be equipped with knowledge of the best use of available resources.

Preferential loans and plantation insurance programs should be designed to help rubber farmer households maintain their plantations and hedge their income risks. Although such insurance programs are not common in Vietnam (Long et al., 2013), programs with monitoring by farmer communities (like micro-credit programs) can be established to attract plantation insurance service suppliers. For example, farmer communities can support each other in the adaptation and monitor insurance claims. Rubber farmer households can thus get preferential insurance packages, if they accept group purchasing. This solution group should concentrate on segment 3 to stimulate this segment's adaptation.

9.2.7 Solution Group of Site Preparation

Rubber farmer households should be equipped with better knowledge of sanitary conditions and quality of the environment in rubber plantations. Waste treatment and sewage drainage can complement some adaptive measures based around site preparation and plantation establishment. Irrigation is based mainly on groundwater extraction. In recent years the state has controlled groundwater exploration due to forecasted consequences of excessive groundwater extraction. However, efficient irrigation technologies have not been widely adopted. There are three reasons for this: farm households do not use electricity at their plantations, so pumps for irrigation systems cannot be used. Most rubber plantations feature hills and slopes. This topography results in higher costs of site preparation. Besides, rubber farmer households also need more information on irrigation technologies, because they assessed the quality of such technologies as not good (Section 8.2.4). Efficient water-saving irrigation models should be widely shown to help farmer households perceive their economic and technical efficiency. This solution group should concentrate on segments 2 and 3 whose land topography is quite steep.

9.2.8 Solution Group of Intercrops

Monoculture and multiculture system choices are climate-sensitive. This choice is important because the intercrop may influence adaptation positively. Crop choices are affected by several factors and they influence farm management practices. Criteria for choosing intercrops with rubber trees include the ability to use these crops for household consumption, the acceptability for intercropping with rubber trees, the improvement in family income, and shorter periods for harvest. The institutional contexts, socio-economic conditions, natural rubber market demand and urbanisation also may affect these choices.

The farm income obtained from poultry and/or bees on plantations is minimal. Therefore, it is important to introduce diversification programs based on farming and non-farm activities. Intercropping using plants and animals has proved successful in some areas, in terms of poverty reduction and plantation development. Such diversification programs need innovations of both the agricultural extension system and rubber farmers. By diversifying, rubber farmer households are able to stabilise their family income. Programs need to equip rubber farmer households with knowledge to operate at the economic optimum. The state should create market channels to help farmer households sell their outputs effectively. These solutions should target segment 2 where rubber trees are immature.

9.2.9 Solution Group of Public Communication

The most common communication means in the study area is television, which is the information tool preferred by rubber farmer households. State policies and rubber development solutions could be disseminated to farmer communities via television. Information must be timely and graspable for rubber farmers, so that they can perceive its significance. Television broadcasts should focus on the perception of climate change and its negative impacts on natural rubber cultivation and production. Technical management standards provided to rubber farmer households should focus on key clonal attributes such as short tapping age, extreme climate and weather resistance, appropriate costs of adoption, high economic and technical efficiency.

Any solution group of opening agricultural-products market is also particularly important in current research on agricultural development, but this macro solution group is excluded in this chapter. This study concentrates on micro solution groups for farm-level adaptation.

The quantitative findings presented in this study will help researchers, decision makers, rubber farmers and related stakeholders address the challenges of farm-level adaptation to climate change. For each segment of rubber farmer households it is possible to improve attributes as needed and enhance features of output efficiency, economies of scale, irrigation facilities, social networks, skilled labour availability and security of tenure. In detail, rural infrastructure and markets are “hard” contributions to improve production conditions. Advanced farming practices, irrigation facilities, skilled labour availability, social networks and security of tenure are “soft” contributions to improve production conditions. These “soft” contributions are of the nature of micro policies.

9.3 Policy Implementation and Conclusion

This chapter drew nine micro policy solution groups of clones, family income, education and training, agricultural extension, tenure, resource supply, site preparation, intercrops and public communication. Macro solution groups of local infrastructure, markets and socioeconomic development are excluded in the scope of this study. Drawing on local practical experiences, a review of the literature and quantitative findings based on modelling of adaptation-vulnerability-preference-capability interrelationships, solution groups are identified for different rubber farmer households. The methodologies in this study are expected to support decision makers and related stakeholders to provide easily accessible tools for farm-level adaptive policy-making.

Policy implementation requires actions by the public and private sectors. The policy responses recommended above cover both practical and theoretical issues, and are based on the quantitative findings. By understanding the four adaptive behaviour types of rubber farmer segments, decision makers, rubber farmers and related stakeholders can start with strong and early actions that facilitate coping in the short term and then adaptation in the long term.

Apart from the highest priority for the policy responses recommended, in the long term the public sector concentrates continuously on research and development of applied models and practices. Information then is filtered and introduced to rubber farmer households through appropriate models, practices and policies. This sector also focuses on investment for local infrastructure and human capital. The private sector is equipped with knowledge and practices to perceive relevant policy aspects and enhance their five types of capital themselves.

Chapter 10 Summary and Conclusions

10.1 Introduction

Farmer adaptation to climate change and variability at the farm level is absolutely essential to reduce the adverse effects caused by prevailing climate and weather changes and to take advantage of beneficial changes if present. Farmer adaptation is also able to reduce the pressures from market and yield uncertainties. This study identified that there has been a gap in approaching climate change adaptation at the farm level comprehensively, especially within farming systems in developing countries. This is a lack of local level assessment of climate change and variability; lack of quantitative assessment of their negative impacts on crop performance; lack of analytical bases on how different types of farmer households adapt to climate change and the determinants of their adaptive responses; and lack of analytical basis for reliable policy recommendations about climate change adaptation among targeted farmer segments. A comprehensive approach that addresses all these research questions has not been attempted before. The findings of this research can assist local policy-makers to address the challenges of climate change and variability. A case study application of the small-scale rubber sector in Southeast Vietnam was used to demonstrate the methods and data required for such a comprehensive approach, and to provide policy recommendations about adaptation of farmer households in the study area. This project has contributed to knowledge, application of methodology, and to the existing literature on this subject.

10.2 Overview of the Study

As efforts to combat climate change through international policies have stalled, adaptation is becoming more urgent for natural rubber producers. Adaptation policies need to be adjusted over time as climate and technologies change, reflecting the fact that local decision makers face policy-making under severe uncertainty. In addition to limitations in resource allocation, and needs for other socio-economic development plans, developing and applying a comprehensive analytical framework will allow local decision makers as well as related stakeholders to manage climate change adaptation in rubber farming systems. This study presented a number of analytical approaches and suggested practical policies based on the research findings.

The comprehensive approach used in this study, in terms of methods of analysis of climate change, climate variability, effect of climate hazards on crop performance, perception, vulnerability, adaptation and logical mechanisms of farmer adaptation, is a methodological contribution beyond what has been done in previous studies. It helps understand the significance and necessity of the research, and makes clear theoretical and practical bases in a particular situation of interest. It introduces steps to conduct the research and understand the requirements (i.e. methods of analysis, data, empirical models, analytical instruments) to meet the purpose of the research.

This study considered three key issues in the study area: preferred adaptive methods to changing climatic conditions, underlying attributes of adaptive measures being practised and reasons that rubber farmer households prefer such adaptive attributes. These measures are changeable over time. However, focusing on a limited number of attributes of adaptive measures (e.g. cost, profit, time, labour availability) allows for a more general application of theory and empirical findings. Therefore, an approach that focuses on attributes is usually more meaningful than a conventional approach focusing on measures.

Questionnaire responses revealed the institutional contexts, socio-economic conditions, and agro-environments in the study area; as well as demographic and farm characteristics of rubber farm households. The information indicated farmer households' vulnerability, their perception and adaptation to climate change, and it provided an overall assessment of rubber cultivation prospects from growers' points of view in the study area. The secondary data at the provincial level helped as an introduction to the research by exploring trends in rubber yields and climate. The survey data obtained through a survey at the farm level are found to be consistent with the provincial dataset, and provide the main source of information to meet the purpose of the study.

10.3 Key Research Findings

10.3.1 Findings from the Secondary Data

There is considerable evidence of climate change and variability in the study area. Climate change is shown through time trends in some outcome variables of climate, while climate variability is shown through differences in some outcome variables of climate between the three provinces studied. There is a negative correlation between drier status of the region and variation of latex yield. Basically, the provincial and farm level data indicate consistent findings regarding the adverse effects of climate change on latex yield.

10.3.2 Findings from the Survey Data

Most rubber farmers in the survey strongly perceived climate change, climate variability and their negative consequences on natural rubber production. Farmer households' incomes were vulnerable to climate change and variability, providing a reason for farmer households to want to adapt to climate change and its associated variability. There is almost no evidence of an adaptive deficit. Farmer households' adaptations are clearly seen at the farm level, but their preferences are heterogeneous among adaptive measures.

Heterogeneous preferences were comprehensively considered in this study. There are three different segments of rubber farmer households in the population. Farmer households in this study have special interest in seven adaptive attributes which are classified into four behaviour types based on methods that (i) increase drought resistance and heavy wind resistance of rubber trees; (ii) allow needs of skilled labour, time availability and investment capital to be met; (iii) allow required technical and economic efficiency to be attained; and (iv) result in early harvesting. The characteristics of each farmer segment are related to their preferences for adaptive attributes, divided into four factor groups. The factor 1 group is concerned with adaptive measures where farmer households may obtain three attributes of availability of (i) skilled labour, (ii) investment capital and (iii) suitable time to conduct tasks. These attributes are related to availability of economic inputs such as capital and labour. Therefore, this group is named *resource attributes*. The factor 2 group is concerned with adaptive measures which improve two attributes (iv) drought resistance and (v) heavy-wind resistance. These attributes are related to clonal technologies and methods that diminish negative impacts of drought and heavy winds on rubber trees. Therefore, this group is named *biological attributes*. The factor 3 group is concerned with adaptive measures which ensure (vi) the technical and economic efficiency of the adoption in natural rubber production. Therefore, this group is named *efficient attributes*. The factor 4 group is concerned with adaptive measures which affect (vii) the harvest timing. This group concentrates on obtaining early yields/income, and it is related to quick economic returns. Therefore, this group is named *early return attributes*. The different behaviour groups can constrain efficient adaptation at the farm level when adaptive measures or policy responses are set up for everyone without matching their particular preferences.

Rubber farmer households in segment 1 have a propensity to prefer *biological attributes*, while they have a propensity not to prefer *efficient attributes*, *resource attributes* and *early return attributes*. Rubber farmer households in segment 2 have a propensity to prefer all the four attribute groups, but *efficient attributes* impacted the most strongly on their utility. Rubber farmer households in segment 3 have a propensity to prefer *early return attributes* and *resource attributes*, while they have a propensity not to prefer *biological attributes* and *efficient attributes*. These findings showed heterogeneity of preferences for adaptive attributes among farmer segments. *Resource attributes* and *early return attributes* are most preferred by rubber farmer households in segment 3, but not most preferred by rubber farmer households in segment 1. In contrast to segment 3, segment 2 has the least regard for these two attributes.

There are 10 farm-level determinants that influence the three farmer segments' heterogeneous preferences for adaptive responses, and influence the probability of being members of a particular segment as follows: (i) certificate of land-use rights, (ii) farmer networks, (iii) hired labour, (iv) net profit per ha, (v) rubber land size, (vi) education level, (vii) household size, (viii) age of rubber trees,

(ix) irrigation facilities, and (x) multiculture systems.

Three adaptive measures considered most preferable in the sample are (i) proper rubber clones, planting materials and sound crop establishment; (ii) rain guard technology; and (iii) correct tapping techniques. Most rubber farmers believed that efforts made to conduct their adaptive methods could also improve latex quality and yield. There is a range of the main constraints to adoption of adaptive measures in the study area. Farmer households showed emphases in four factors: (i) lack of information about potential climate change; (ii) inaccessibility to the market system; (iii) lack of techniques and knowledge in the three development stages of rubber trees; (iv) and lack of investment capital. Other constraints are present, including (v) inaccessibility to suitable land; (vi) lack of skilled labour; (vii) rationing of good clone sources and planting materials; and (viii) insecurity of tenure. Interestingly, only very few rubber farmer households did expect a transition from rubber plantations to other crops in order to have a better income.

10.3.3 Associated Policy Solution Groups

This study identified nine micro policy solution groups related to clones, family income, education-training, agricultural extension, tenure, resource supply, site preparation, intercrops and public communication. These solution groups cover the three aspects of impact dimension (spatial and temporal), application scope (local) and association scale (local governmental and individual). They are expected to fit different farmer segments' adaptive preferences and to ensure the efficacy of policy responses in terms of empirical and feasible contributions. Macro solution groups of local infrastructure, markets and socioeconomic development are excluded in the scope of this study. This study concentrates particularly on micro solution groups for farm-level adaptation as follows.

(**1**) Less-improved old clones should be replaced with new better clones. Agricultural management agencies should assess the quantity and quality of local private clone suppliers. The state should support clone suppliers in terms of further research and development, particularly the suitability of clones to local changing climatic conditions. When new clones are widely introduced, they must be associated with the necessary supports of (i) investment capital, (ii) skilled workforce, (iii) application knowledge in choosing clones compatible with their farm features, and (iv) experimental models. Disseminating experiences of local rubber companies, which are leading in the application of new clones, can spillover to rubber farmers. These solutions should target segments 1 and 3.

(**2**) It is important to introduce diversification programs involving farming and non-farm activities. Encouraging adaptive methods that help increase latex yield and decrease yield variability. Encouraging programs that help improve quality of the workforce and create more work opportunities for farmers. This solution group helps increase family income and should concentrate on segments 2 and 3.

(**3**) Training activities for fertiliser application, planting, nursing rubber trees and tapping for latex should be evenly distributed among rubber growing regions and rubber farm households. These activities should be enhanced in terms of quantity and quality of teaching and learning in order to increase the supply of skilled workers. Issues in relation to climate change and variability affecting rubber trees need to be upgraded and disseminated to rubber farmer households. The young should be educated on the potential of the rubber industry and career opportunities it brings. Rubber farmer households should be equipped with knowledge of skilled labour employment. Common diseases of rubber trees should be treated simultaneously to reduce the risk of reinfection.

(**4**) Efforts should be made to enhance agricultural extension activities, quality as well as quantity of extension services suppliers and local extension workforce. Extension activities should also focus on providing market information and establishing good models of rubber production to spread good practices to farmer households. Rubber farmer networks should be equipped with within-network mutual skills to adopt the methods recommended by extension services. Rubber farmer households should follow a range of technical standards in the rubber industry strictly. This ensures they are able to compare and adjust their internal capacity in terms of plantation development and product quality. This solution group should concentrate on all segments, but segments 2 and 3 should receive more attention to establish local rubber farmer networks.

(**5**) Landholders should be informed in advance if there are plans for a transition in classification from agricultural land into homestead land or land for other strategic priorities. Rubber farmer households should be equipped with the knowledge on efficient use of a land unit and on the best use of available resources. There is still the potential for increasing latex yield at the farm level; therefore, land for rubber development should not be expanded. This solution group should concentrate on segments 2 and 3.

(**6**) Preferential loans and plantation insurance programs should be designed to help rubber farmer households maintain their plantations and hedge their income risks. This solution group should concentrate on segment 3.

(**7**) Rubber farmer households should be equipped with better knowledge of sanitary conditions and quality of the environment in rubber plantations. Efficient water-saving irrigation models should be widely shown to help farmer households perceive their economic and technical efficiency of adoption visually. This solution group should concentrate on segments 2 and 3.

(**8**) Rubber farmer households should be equipped with the knowledge on intercropping using plants and animals. The state should help create market channels to help farmer households sell their outputs effectively. These solutions should target segment 2.

(**9**) The most common communication means is found to be television. It should be used efficiently in terms of broadcast time and duration to disseminate necessary information. Information must be timely and graspable for rubber farmers. Broadcasts should focus on the perception of climate change and the negative impacts of climate change on natural rubber cultivation and production. Technical management standards provided to rubber farmer households should focus on key clonal attributes (e.g. short tapping age, extreme climate resistance, appropriate costs of adoption, high economic and technical efficiency).

Finally, rural infrastructure and markets should be improved. They are "hard" contributions to improve production conditions. In addition, advanced farming practices, irrigation facilities, human capital, social networks and security of tenure are "soft" contributions to improve production conditions. Policy implementation requires actions by public and private sectors.

By understanding the four adaptive behaviour types and related segments of rubber farmer households, decision makers, rubber farmers and related stakeholders can start with strong and early actions facilitate farmers' coping in the short term and then their adaptation in the long term. The public sector provides research and development (R&D) and extension support. Information is provided to rubber farmer households through appropriate models, practices and policies. This sector also invests in local infrastructure, markets and human capital. The private sector is equipped with knowledge and practices to perceive relevant policy aspects and enhance their five types of capital themselves.

10.4 Contribution of the Study

10.4.1 Contribution to Policy Implications

This study uses a case study demonstration in Southeast Vietnam, but the approach can be applied in a broader context for investigating climate change adaptation in agriculture and national programs of climate change. The study shows the heterogeneous adaptive response types among different farmer segments. This result implies that support for climate change adaptation at the farm level should not be based on homogeneous policies. The findings also help confirm that adaptation in crop farming systems is locally specific and is clearly seen at the farm level. This finding can assist local decision-makers in implementing adaptation strategies suited to prevailing climate and weather changes in a local area. Similarly, policy design and management must account for variation in farmer households' adaptive responses. The methodologies and findings in this study are expected to support decision makers and related stakeholders to provide useful tools for farm-level adaptive policy-making.

10.4.2 Contribution to the Literature and Knowledge on Adaptation at the Farm Level

The findings of this study fit into, and add to, the existing literature on and the knowledge of climate change adaptation at the farm level. This study addresses a gap in research in developing countries regarding the comprehensive assessment of climate change adaptation at the farm level. Such a comprehensive approach contributes to successful adaptation at the farm level. It contributes to the literature on heterogeneous preferences for adaptive measures at both the individual and the community level. This study shows that the needs of policy-making are better sewed by investigating at the segment level rather than by analysing individual farmers' practices, and by approaching adaptive attributes rather than by approaching adaptive measures in general. Besides farmer households' perception of and vulnerability to climate change and variability, there is a link between their adaptation and determinants of their adaptive responses. This study thus provides better insight into and understanding of research problems, thereby facilitating the designing better policies for such problems.

The analysis highlights the importance of research on heterogeneous preferences, and it contributes to the knowledge of how to apply the LCM (the stated choice experiment method) in a farming context. The comprehensive approach used in this study is of general interest, and it provides guidance to conduct similar studies on other farming systems and design of successful adaptation policies.

10.5 Area for Enhancement and Future Research

There are some limitations to the secondary and primary data used in this study, which are opportunities for lessening these limitations would enhance this research. For example, different clones are impacted differently by climate change and variability. There is no detailed information about yields and adoption types of different clones, so adoption of clones is assumed to be homogeneous in the climate-yield relationships estimated with secondary data. There was insufficient access to detailed climate data, so more appropriate models of climate-yield relationships could not be estimated. There may be other adaptive measures, attributes and determinants that are omitted from the study. These variables should be identified and included in future studies.

This study is novel in the research context and similar studies need to be conducted in different study areas and in different farming systems, so that comparisons between research results could be obtained. Based on farmer households' preferences for adaptive attributes, this study also provides background for further research on cost-benefit analysis and/or cost-effectiveness analysis of each adaptive option available. These kinds of research require time to conduct, funds and knowledge in these subjects.

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Appendices:

Appendix 1: Summary statistics of rubber farm household characteristics in the study area

No.	Description (N = 430)	Mean	SD	Min	Max
1	Latex yield (tonnes/ha)	2.04	0.72	0.33	4.33
2	Sells liquid latex as a main output (%)	91.42			
3	Sells latex at local collecting stores (%)	63.64			
4	Buys agricultural inputs at local markets (%)	91.01			
5	Perceives an increase in input costs (%)	85.55			
6	Believes latex prices will increase and marketing arrangements are effective (%)	56.64			
7	Has access to credit (%)	61.61			
8	Credit source from rural usury (%)	1.22			
9	Prefers prepayment from local traders (%)	60.10			
10	Has other social commitments (%)	47.00			
11	Participates in farmer groups (%)	56.80			
12	Has frequent contact with brokers, latex processing and rubber product manufactories (%)	82.05			
13	Has property rights over the land (%)	83.01			
14	Has access to climate information (%)	88.29			
15	Has access to extension services (%)	52.58			
16	Received training on rubber farming (%)	92.79			
17	Has obtained subsidies (%)	19.48			
18	Has main income from agriculture (%)	87.20			
19	Net profit per rubber ha (million VND)	44.25	19.31	3.00	170.00
20	*Spearman* correlation coefficients between latex yield and net profit by province	0.56**			
	Binh Phuoc	0.52**			
	Dong Nai	0.23*			
	Tay Ninh	0.39**			
21	Has a combination of poultry and/or bees (%)	15.96			
22	Has main occupation other farming (%)	28.37			

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Appendix 1: Continued.

No.	Description (N = 430)	Mean	SD	Min	Max
23	Has non-farm income (%)	68.16			
24	*Spearman* correlation coefficients between rubber land size and latex yield	0.20**			
25	*Spearman* correlation coefficients between rubber land size and net profit	0.20**			
26	Total land area (ha)	4.89	6.00	0.20	50.00
27	Rubber farm size (ha)	4.65	5.84	0.10	50.00
28	Owns 2 plots or more of rubber plantations (%)	45.83			
29	Distance to important places (km)	13.31	8.46	0.5	61.25
30	Has convenient access to irrigation (%)	54.52			
31	Extracts groundwater (%)	73.73			
32	Considers supply of irrigation technologies not good (%)	20.99			
33	Uses electricity on farm (%)	26.05			
34	Uses irrigation technologies (%)	9.63			
35	Age of household head (years)	49.53	10.72	21.00	89.00
36	*Spearman* correlation coefficients between age and experience of household head by province	0.46**			
	Binh Phuoc	*0.57***			
	Dong Nai	*0.40***			
	Tay Ninh	*0.50***			
37	Belongs to ethnic minority group (%)	2.33			
38	Household head is married (%)	96.05			
39	Education level of household head (years)	9.66	3.98	0.00	20.00
	Binh Phuoc	10.21			
	Dong Nai	9.77			
	Tay Ninh	8.96			
40	Years involved in farming (years)	19.68	10.32	1.00	50.00
41	Household size (persons)	4.62	1.85	1.00	15.00
42	Considers supply of hired labour not good (%)	8.87			

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Appendix 1: Continued.

No.	Description (N = 430)	Mean	SD	Min	Max
43	Age of rubber trees (years)	10.08	3.99	1.00	24.00
44	Age of first tapping (years)	5.43	0.74	3.00	8.00
45	*Spearman* correlation coefficients between yield and age of first tapping by province	-0.17**			
46	Stand density (trees per ha)	528.26	81.16	110.00	900.00
47	*Spearman* correlation coefficients between yield and density by province	0.21**			
48	Applies multiculture systems (%)	39.67			
49	Hires labour (%)	65.39			
50	Yield loss in 2013 (%)	16.96			
51	Observes changes in climate and weather variables (%)	97.19			
52	Conducts adaptive measures (%)	99.07			
53	Predicts a percentage (%) of increased yield when conducting adaptive measures	18.85			
54	Predicts an increase in latex quality when conducting adaptive measures (%)	97.14			
55	Expects a transition from rubber plantation to other crops (%)	9.22			

*: $p < 0.05$ and **: $p < 0.01$

Source: Estimates using the survey data

Appendix 2: Questionnaire for farm households that grow rubber trees in Southeast Vietnam

Phone number:

QUESTIONNAIRE FOR FARM HOUSEHOLDS
THAT GROW RUBBER TREES IN SOUTHEAST VIETNAM

General information:

Name of respondent:	…………………..………
Name of village:	…………………..………
Name of district:	…………………..………
Name of province: (Circle an appropriate name)	**Binh Phuoc, Dong Nai, Tay Ninh**
Total land size	…………………..………ha

I. Demographic information

1. Are you a household head? (Tick ☑ if appropriate): Yes ☐ No ☐
2. Year of birth: …………………..………
3. Gender (Tick ☑ if appropriate): Male ☐ Female ☐
4. Ethnic group (Tick ☑ if appropriate): Kinh ☐ S'tieng ☐ Other ☐
5. Marital status
   (Tick ☑ if appropriate): Single ☐ Married ☐ Divorced ☐
6. Years of schooling (in number):……….………years.
7. Which activities have you received training on?

Activities	Tick ☑ if appropriate
1. Planting and nursing rubber trees	☐
2. Fertiliser application	☐
3. Protecting against rubber plant diseases	☐
4. Tapping for latex	☐
5. Processing rubber latex	☐

8. Your current occupation:

    Main occupation[66] (Please write): …………………….………

    Secondary occupation[67] (Please write): …………………….………

9. Household size:

Household size	Count the number of persons
Adult members (Above 15 years of age)	……………..………persons
Child members (Under 14 years of age)	……………..………persons
Not in workforce and/or disabled members	……………..………persons
Male family members	……………..………persons
Members earning off-farm income	……………..………persons
Total	**……………..………persons**

10. Main income sources of your family is from:
    (Tick ☑ if appropriate): Agriculture ☐ Non-agriculture ☐

11. How long have you been involved in farming (in number): ………years.

II. Socio-economic information

12. Are you a member of political organisations, socio-political organisations or occupational associations? (Tick ☑ if appropriate): Yes ☐ No ☐

13. Are you a member of rubber farmer groups at your locality?
    (Tick ☑ if appropriate): Yes ☐ No ☐

14. How long have you been involved in the activities at sub-items 12 and 13?
    (in number): ………….. years.

15. Do you have frequent contact with brokers, latex processing or rubber product manufactories? (Tick ☑ if appropriate): Yes ☐ No ☐

16. In which year were most of your rubber trees planted? (in year): …………

17. At what stage do you start tapping your rubber clones? (in number): …….years.

18. How many rubber trees are planted per ha on average? (in number):……. trees.

[66] Write down the main occupation, if the respondent usually does work in an activity other than farming, for example, as a public servant.

[67] Write down the secondary occupation, if the respondent sometimes does other work besides farming and the main occupation, for example, as a carpenter.

19. What are the main types of clones of your rubber trees?
    (Enter names): ………………………………………….…….
20. What are the main sources of your rubber clones?
    State nurseries ☐ Private nurseries ☐ Self-preparation ☐
21. Which product types below do you usually sell?
    Latex ☐ Coagulated latex ☐
22. Where do you usually sell your produce?
    (Tick ☑ if appropriate): At farm plantations ☐ At local collecting stores ☐
23. What percentage of your produce do you usually sell at local market? …………%
24. Where do you usually buy your agricultural inputs?
    (Tick ☑ if appropriate): At urban market ☐ At local market ☐
25. How far is it from your farm to the closest places of each type:

The closest places	**Distance**
Local market	…………………..………km
Urban market	…………………..………km
Commune road	…………………..………km
Administration centres	…………………..………km

26. Could you estimate your average latex yield per ha in the last year?
    (in number):……. tonnes/ha.
27. Please estimate your family's net profit from rubber per ha in the last year:
    (in number): ………… million VND/ha.
28. Please estimate your family's income from non-farming activities in the last year. For example, salary, remittances, etc.
    (in number): ………… million VND.
29. Is your rubber plantation certified as a standard farm by the government?
    (Tick ☑ if appropriate): Yes ☐ No ☐

30. Characteristics of your rubber-growing land:

Type of land	Amount
Owned land	……………………..………ha
Source of the owned land:	(Tick ☑ if appropriate):
Bought	Yes ☐ No ☐
Inherited	Yes ☐ No ☐
Rented land	……………………..………ha
Homestead land from local government	……………………..………ha
Other	……………………..………ha
Total of rubber growing land size	**……………………..………ha**

31. Soil type (Tick ☑ if appropriate):
    Ferralsols (Red basalt) ☐ Acrisols ☐ Others ☐
32. Land topography (Tick ☑ if appropriate):
    Hills ☐ Gentle slopes ☐ Plains ☐
33. How many plots of rubber growing land are you using? (in number):…………
34. Do you have any certificate of land-use rights?
    (Tick ☑ if appropriate): Yes ☐ No ☐
35. Please point out the main types of waste treatment in your plantation.

Types of waste treatment	Tick ☑ if appropriate
Garbage is collected	☐
Garbage is transported to a common dump	☐
Garbage is buried or burned	☐
Garbage is thrown anywhere	☐
Garbage is treated in other ways	☐

36. Please point out the main types of sewage drainage system in your plantation.

Types of sewage drainage system	Tick ☑ if appropriate
Sewage drainage system with gutter with cover	☐
Sewage drainage system with gutter without cover	☐
Other types of sewage drainage system	☐
No sewage drainage system	☐

37. Do you bring up poultry and/or bees on your rubber cultivation?
(Tick ☑ if appropriate): Yes ☐ No ☐

III. Farmer perception of climate change

38. Do you prefer monoculture system (only rubber trees) to multiculture system (intercropping between rubber trees and other crop types) in the first three years? (Tick ☑ if appropriate): Yes ☐ No ☐

39. Please provide your opinion about the supply of agricultural inputs:

Inputs	Opinion (Tick ☑ for only one option per row)			
	Not good	**Medium**	**Good**	**Very good**
1. Young plants and planting materials	☐	☐	☐	☐
2. Fertiliser	☐	☐	☐	☐
3. Herbicide and other agrochemicals	☐	☐	☐	☐
4. Hired labor	☐	☐	☐	☐
5. Irrigation technology	☐	☐	☐	☐

40. Have you perceived any change in climatic conditions at your locality over the past 20 years? (Tick ☑ if appropriate): Yes ☐ No ☐
If yes, please point out climate variables that you think have changed, then describe how they have changed.

Climate variables	Opinion (Tick ☑ for only one option per row)			
	Do not know	**Unchanged**	**Decreased**	**Increased**
1. Temperature	☐	☐	☐	☐
2. Precipitation	☐	☐	☐	☐
3. Drought	☐	☐	☐	☐
4. Heavy wind	☐	☐	☐	☐
5. Hours of sunshine	☐	☐	☐	☐
6. Soil moisture	☐	☐	☐	☐
7. Groundwater	☐	☐	☐	☐
8. Surface water	☐	☐	☐	☐

41. Do you believe that input costs are increasing?

(Tick ☑ if appropriate): Yes ☐ No ☐ Unchanged ☐

42. Do you usually hire labor for tapping?

(Tick ☑ if appropriate): Yes ☐ No ☐

43. Do you think latex yield is affected negatively by the climate variables? For example, high temperature, low precipitation and severe droughts.

(Tick ☑ if appropriate): Yes ☐ No ☐

44. What is your opinion about the relationship between these variables and latex yield?

Level of severity	**Tick ☑ if appropriate**
1. Very severely affected	☐
2. Severely affected	☐
3. Moderately affected	☐
4. Slightly affected	☐
5. Do not know	☐

45. Which disease below is mostly challenging to you?

List of diseases	**Tick ☑ if appropriate**
1. Stem and trunk diseases resulting in falling leaves	☐
2. Pink fungi disease resulting in bark dryness and plant death	☐
3. Tapping panel dryness resulting in low latex yield	☐

46. What percentage of total latex yield was damaged in the last year by above climate variables? (Enter number): ………….%

IV. Farmer adaptation to climate change

47. Do you have access to extension services, particularly in rubber cultivation?

(Tick ☑ if appropriate): Yes ☐ No ☐

If yes, please point out the sources (Tick ☑ if appropriate):

Newspapers ☐ Television ☐ Radio ☐

Neighbours ☐ Leaflets ☐ Learning by doing ☐

Extension officials ☐ Retailers ☐ Suppliers of crop clones ☐

Research centers ☐

48. Do you get any climate and weather information in advance?
(Tick ☑ if appropriate): Yes ☐ No ☐
If yes, please point out its sources from (Tick ☑ if appropriate):
Newspapers ☐ Television ☐ Radio ☐
Extension services ☐ Neighbours ☐ Word of mouth ☐
49. Do you have access to credit?
(Tick ☑ if appropriate): Yes ☐ No ☐
If yes, please point out the sources (Tick ☑ if appropriate):
Provincial level ☐ Local levels ☐ Rural usury ☐
50. Do you receive any type of agricultural subsidies from the government? For example, agricultural inputs (young plants, planting materials, fertiliser, pesticide and herbicide), cash and others (irrigation technology).
(Tick ☑ if appropriate): Yes ☐ No ☐
51. Does your rubber-growing land have access to irrigation facilities?
(Tick ☑ if appropriate): Yes ☐ No ☐
If yes, please point out the water sources (Tick ☑ if appropriate):
Groundwater (drilled wells) ☐ Surface water (ponds or dug wells) ☐
52. Do you use any water-saving irrigation technology?
(Tick ☑ if appropriate): Yes ☐ No ☐
If yes, please point out the technological type (Tick ☑ if appropriate):
Spray irrigation technology ☐ Drip irrigation technology ☐
53. What percentage of your total rubber-growing land is under irrigation?
(Enter number): …………..%
54. Do you usually apply more fertiliser than amounts recommended by extension services in order to offset losses caused by above climate variables?
(Tick ☑ if appropriate): Less than ☐ More than ☐ It fluctuates ☐
55. Do you have access to electricity in general at your farm?
(Tick ☑ if appropriate): Yes ☐ No ☐
If yes, please point out your satisfaction (Tick ☑ if appropriate):
Adequate for running pumps ☐ Inadequate for running pumps ☐
56. Have you conducted any change to your farming practices, due to changes in climatic conditions to reduce adverse effects?
(Tick ☑ if appropriate): Yes ☐ No ☐

57. What adaptive measures have you conducted to reduce adverse effects?

Adaptive measures	Please put ☑ if appropriate
I. Planting stage	
1. Using proper ground preparation	☐
2. Choose proper rubber clones, planting materials and sound crop establishment	☐
II. Nursing stage	
3. Alter the fertiliser application strategies	☐
4. Employ spray and drip irrigation technologies	☐
5. Apply water conservation techniques	☐
6. Apply soil conservation techniques	☐
III. Harvesting stage	
7. Employ rain guard technology	☐
8. Apply correct tapping techniques	☐
9. No adaptation	☐

58. Which of these adaptive measures is the most important?

(Refer to number): …………..

59. Please point out attributes related to each adaptive measure chosen

(Tick your agreement level from 1 to 5 into ☐ for each adaptive measure chosen if appropriate).

1	**2**	**3**	**4**	**5**
Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**

Planting stage attribute group	**Adaptive measures**	
	Proper ground preparation (1)	**Proper clones, planting materials and sound crop establishment (2)**
For example, if in Table 57, under number (2) **Proper ground preparation**, you chose **Resistance to drought** with **Agree**, please write **4** in the box	☐ **4**	☐
1. Resistance to drought	☐	☐
2. Resistance to heavy winds	☐	☐
3. Resistance to plant diseases	☐	☐
4. Skilled labor availability	☐	☐
5. Investment capital availability	☐	☐
6. Ability to conduct tasks at the suitable time	☐	☐
7. Security of land-use rights	☐	☐
8. Ability to apply appropriate techniques and knowledge	☐	☐
9. Availability of institutional support	☐	☐
10. Availability of market inputs and services	☐	☐
11. Actions resulting in early harvest	☐	☐
12. Actions resulting in better latex quality	☐	☐
13. Actions resulting in high yield	☐	☐
14. Technical and economic efficiency of the method	☐	☐

(Tick your agreement level from 1 to 5 into ☐ for each adaptive measure chosen if appropriate)

1	2	3	4	5
Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**

Nursing stage attribute group	**Adaptive measures**			
	Fertiliser application (3)	**Irrigation technologies (4)**	**Water conservation (5)**	**Soil conservation (6)**
For example, if in Table 57, under number (5) **Water conservation techniques**, you chose **Investment capital availability** with **Disagree**, please write **2** in the box	☐	☐	☐ **2**	☐
1. Resistance to drought	☐	☐	☐	☐
2. Resistance to heavy winds	☐	☐	☐	☐
3. Resistance to plant diseases	☐	☐	☐	☐
4. Skilled labor availability	☐	☐	☐	☐
5. Investment capital availability	☐	☐	☐	☐
6. Ability to conduct tasks at the suitable time	☐	☐	☐	☐
7. Security of land-use rights	☐	☐	☐	☐
8. Ability to apply appropriate techniques and knowledge	☐	☐	☐	☐
9. Availability of institutional support	☐	☐	☐	☐
10. Availability of market inputs and services	☐	☐	☐	☐
11. Actions resulting in early harvest	☐	☐	☐	☐
12. Actions resulting in better latex quality	☐	☐	☐	☐
13. Actions resulting in high yield	☐	☐	☐	☐
14. Technical and economic efficiency of the method	☐	☐	☐	☐

(Tick your agreement level from 1 to 5 into ☐ for each adaptive measure chosen if appropriate)

1	2	3	4	5
Strongly disagree	**Disagree**	**Neutral**	**Agree**	**Strongly agree**

Harvesting stage attribute group	**Adaptive measures**	
	Rain guard technology (7)	**Correct tapping techniques (8)**
For example, if in Table 57, under number (8) **Correct tapping techniques**, you chose **Security of land-use rights** with **Neutral**, please write **3** in the box	☐	☐ **3**
1. Resistance to drought	☐	☐
2. Resistance to heavy winds	☐	☐
3. Resistance to plant diseases	☐	☐
4. Skilled labor availability	☐	☐
5. Investment capital availability	☐	☐
6. Ability to conduct tasks at the suitable time	☐	☐
7. Security of land-use rights	☐	☐
8. Ability to apply appropriate techniques and knowledge	☐	☐
9. Availability of institutional support	☐	☐
10. Availability of market inputs and services	☐	☐
11. Actions resulting in early harvest	☐	☐
12. Actions resulting in better latex quality	☐	☐
13. Actions resulting in high yield	☐	☐
14. Technical and economic efficiency of the method	☐	☐

60. Would you like to receive prepayment from local traders and pay them back in rubber latex later? (Tick ☑ if appropriate): Yes ☐ No ☐

61. What are barriers in applying these adaptive measures?

Barriers to adaptation	Please put ☑ if appropriate
1. Lack of skilled labour	☐
2. Lack of investment capital	☐
3. Lack of information about potential climate change	☐
4. Lack of techniques and knowledge in planting, nursing and harvesting stages	☐
5. Rationing of good clone sources and planting materials	☐
6. Inaccessibility to the market system	☐
7. Inaccessibility to suitable land	☐
8. Insecurity of tenure	☐

V. Farmers' overall assessment of rubber cultivation prospects

62. Please predict if above adaptive measures are conducted, by how much will your latex yield increase? (Enter number): ………….%

63. Please predict if above adaptive measures are conducted, will latex quality increase? (Tick ☑ if appropriate): Yes ☐ No ☐

64. Do you believe that latex prices will continue to be profitable and that marketing arrangements are effective?
(Tick ☑ if appropriate): Yes ☐ No ☐

65. Do you expect a transition from your rubber plantation to other crops or other land-use types for better income? (Tick ☑ if appropriate): Yes ☐ No ☐
If yes, what is the planned land-use?
(Enter names): …………………………………………………...

Thank you for your participation!