Master Thesis

In the study program "Environmental Management"

Assessing the Provisioning Ecosystem Service Food Rice and its Linkages to Human Well-being in Lao Cai and Tien Giang Province of Vietnam

Presented by

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Abstract

Population growth in Asia lays a stress on rice production to ensure food security for 60% of the world's population. In order to enable sustainable development of rice production, it is crucial to investigate human well-being of the rice farmers and reveal connections of the provisioning ecosystem service food rice and human well-being. As Vietnam is one of the largest rice producers and exporters in the world, the study chose Lao Cai and Tien Giang provinces of Vietnam as the research regions. Indicators were used in this study as tool enabling the assessment of human well-being and the provisioning ecosystem service food rice in the past and present.

Face-to-face surveys were conducted in Lao Cai in April 2013 and in Tien Giang in May 2013. Data from the statistical database of the General Statistics Office of Vietnam and data from the survey were analyzed to find out trends of each indicator. The adapted indicator sets were used in a pilot attempt to assess human well-being and the provisioning ecosystem service food rice in the study regions. Trends of human well-being of rice farmers and the provisioning ecosystem service food rice in each region and the conceptual linkages between the two domains are the outcomes of this study.

Keywords: Human well-being, provisioning ecosystem service food rice, indicator, linkages, rice production, Lao Cai, Tien Giang.

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Dedication

This thesis is dedicated to my grandfather Trần Hồng Lạc.

You are always missed.

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List of Abbreviations

BMBF	Bundesministerium für Bildung und Forschung – German Federal Ministry of Education and Research
CBD	Convention on Biological Diversity
FAO	Food and Agriculture Organization
GSO	General Statistics Office of Vietnam
IPAM	Institute of Policy and Management, formerly CEPSTA (Center for Policy Studies and Analysis)
LEGATO	**L**and-use intensity and **E**cological En**G**ineering – **A**ssessment **T**ools for risks and **O**pportunities in irrigated rice based production systems
MA	Millennium Ecosystem Assessment
MARD	Ministry of Agriculture and Rural Development of Vietnam
NEF	New Economics Foundation
OECD	Organization for Economic Cooperation and Development
pp	percentage points
SD	standard deviation
SRPPC	Southern Regional Plant Protection Center
TEEB	The Economics of Ecosystems and Biodiversity
VND	Vietnamese Dong
yr.	year

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1. Introduction

Rice (*Oryza sativa*) is one of the three most important food crops in the world and mostly consumed in Asia (GRiSP, 2013). Populations in all Asian countries, except Japan and Kazakhstan, are predicted to grow until 2050 (World Population Statistics, 2013). The population growth will put more pressure on the rice production systems. In order to ensure food security, a better understanding of the rice production systems and their relations to the society is needed.

This chapter will give an introduction of rice agriculture, the concepts of ecosystem services and human well-being. The linkages of ecosystem services and human well-being will be addressed, leading to the research agenda of this study.

1.1 Rice Agriculture

Even though the history of rice is still under debate and perhaps no one could claim the original place and the beginning of rice cultivation history (Li et al. 2007, Fuller et al. 2011), it is obvious that rice has always been an important source of human nutrient intake since ancient time. According to Zong et al. (2007), the oldest evidence of rice cultivation in the coastal wetlands of eastern China showed that rice cultivation there began 7700 calibrated years before present. Additionally, pottery shards with the imprints of grains and husks of *Oryza sativa* were found at Non Nok Tha in Thailand and plant remains that were dated 10000 B.C were discovered in the Spirit Cave at the border of Thailand and Myanmar (GRiSP, 2013).

The first sections of this subchapter will give an introduction to the role of rice to humanity and food security. An overview of rice production and consumption in Vietnam is given in the end of this subchapter.

1.1.1 Importance of Rice to Humanity

Rice is one of the most important grains which formed an integral part of human history. Countless traditions of humanity are bound to rice and rice has been interwoven into the oldest religious customs (Lee, 1994). Regarding worldwide production, rice was ranking the second after maize in the year 2012 (FAOSTAT, 2014). 90 % of the world's rice is grown and consumed in Asia, home of 60 % of the world's population (World Population Review, 2014) on about 11 % of the world's cultivated land (Buggenhout et al, 2013). A person in Vietnam consumes on average 150 kg to 200 kg of rice each year, which supplies 50 % to 70 % of the

calorie intake and approximately 60 % of daily protein consumption (GRiSP, 2013). Table 1 which was compiled from the FAO database shows the whole picture of world food production in 2009. It can be seen that rice supplied 19 % of global human per capita energy intake and 13 % per capita protein intake in 2009 (Table 1).

Table 1: World food picture in 2009 (From GRiSP, 2013, p. 12).

Human population (million)	6,815.8							
Land use, 2009 (million ha)								
Total land area	13,003.5							
Arable land	1,381.2							
Permanent crops	152.1							
Permanent meadows and pastures	3,355.7							
Forest area	4,038.7							
Other land	4,088.0							
Food production					Per capita/day		Share in nutritional intake (%/day)	
Crop	Area (million ha)	Production (million t)	Food (million t)		Calories (kcal)	Protein (g)	Calories (kcal)	Protein (g)
Rice (rough)	158.5	684.6	531.9	65% milling rate	536	10.1	18.9	12.7
Maize	158.8	819.2	114.0	80% for feed	141	3.4	5.0	4.3
Wheat	224.6	686.6	439.4	70% milling rate	532	16.2	18.8	20.4
Millet and sorghum	74.2	83.0	47.2	30% milling rate	59	1.7	2.1	2.1
Barley and rye	60.8	169.9	12.0	70% milling rate	13	0.4	0.5	0.5
Oats	10.2	23.2	3.6	65% milling rate	3	0.1	0.1	0.1
Potatoes	18.7	332.1	217.3	60% for feed	61	1.4	2.2	1.8
Sweet potatoes and yams	13.0	150.9	81.0	50% for feed	33	0.4	1.2	0.5
				Subtotal	1,378	33.7	48.7	42.5
				All foods	2,831	79.3	2,831	79.3

Table 2 shows the nutrient content of different rice varieties and processing stages of rice. Unmilled rice contains more nutrients than milled or polished white rice.

Table 2: Types of rice and theirs nutrient content (From FAO, 2004, p. 2)

Type of rice	Protein *(g/100g)*	Iron *(mg/100g)*	Zinc *(mg/100g)*	Fibre *(g/100g)*
White – polished[a]	6.8	1.2	0.5	0.6
Brown[a]	7.9	2.2	0.5	2.8
Red[b]	7.0	5.5	3.3	2.0
Purple[b]	8.3	3.9	2.2	1.4
Black[a]	8.5	3.5	-	4.9

Sources: [a] = Association of Southeast Asian Nations (ASEAN) food composition table; [b] = Chinese food composition table.

Rice shaped the dietary habits of its cultivators and consumers (FAO, 2004a). Each rice consuming country eats rice in its own traditional way. Depending on the regions, rice can be eaten with fish or meat, or with legumes. In Asian countries, the term “rice-fish societies” has originated from the combination of rice and fish (GRiSP, 2013). In Puerto Rica, “rice and beans” is considered as the national dish (Noel et al., 2009). In Thailand and Vietnam, they do not only eat rice in its original form, but also make a vast variety of dishes from rice noodles and rice powder (Tran 2002; Wongcha-Um 2009).

Apart from being a major staple food, rice also plays an important role in human culture. *Oryza sativa* has been a crop that was planted by emperors and kings, offered to the Gods, eaten by both the wealthy and the poor (Lee, 1994). Moreover, rice is the grain that has shaped the history, culture, diet and economy of billions of people of Asia (Gomez, 2001). The relation between humans and rice has been the inspiration for many cultural traditions and activities in Asian countries. People do not only eat rice but sleep on rice straw, drink rice liquor and offer rice to their Gods and ancestors (GRiSP, 2013). Land opening festivals can be found everywhere from China to Thailand and Vietnam with different rituals and ceremonies, but having the same purpose of marking the beginning of a new crop and praying for a bumper harvest. In many different cultures rice gods and rice goddesses exist. The Japanese call their rice god Inari (Ortabasi, 2013), the people in Bali and Java worship Dewi Sri as the goddess of rice and fertility (Resink, 1997). In Thailand, Mae Posop is known as the name of the rice goddess. Mae Posop and Dewi Sri are worshipped in a similar way with respect by their people (Gomez, 2001).

Rice has been a source of inspiration to countless numbers of folk songs and poems. In Vietnam, mothers sing nursery rhythms about rice to their children. Every kid knows stories, idioms and proverbs about rice by heart (Nguyen, 1999). Since being a small child, everyone is aware that each grain of rice is a gem and it should not be wasted in any way.

1.1.2 Food Security

Rice is the primary staple food of more than half of the world population (GRiSP, 2013). Asia is the region where rice is produced and consumed the most. Of the three major crops (rice, wheat and maize), rice is the most important regarding the human consumption in low- and lower-middle-income countries (GRiSP, 2013). It is estimated that in the next 36 years two billion people need to be fed additionally, when the world population reaches nine billion (FAO, 2009). Seck et al. (2012) projected global rice consumption to rise from 439 million tons (milled rice) in 2010 to 496 million tons in 2020 and further increase to 555 million tons in

2035. An annual yield growth of 1.2 % to 1.5 %, compared with current yield growth of less than 1 % will be needed to make sure that rice is still affordable to millions of poor people in the world (Mohanty et al., 2013). It is crucial to ensure that the consumer's daily bowl of rice is safe and in good quality, especially in such countries, where rice is not only the most important staple food, but rice farming is also one of the main economic activities (FAO, 2004).

Food security is a complex phenomenon that has been long discussed from different aspects. Figure 1 shows a simple framework from Timmer and Cabot (2010) explaining the food security issues in Asia from an economic point of view. At the starting point, the upper left box, policy makers have to deal with issues at the macro-level in a short time frame. To the extent of budget cost, they are the most concerned about the welfare of poor families. In the short term, they do their best to stabilize the prices of food and send transfer payments to households which are affected during a food crisis, when the prices elevate dramatically. On the long run, policy makers apply measures at the macro-level to "stimulate inclusive, pro-poor economic growth, and sustain that growth for decades in order to have a measurable impact on poverty" (Timmer and Cabot, 2010, p. 3). The bottom right box indicates when food security is achieved, i.e. to have reliable and sustainable access to nutritious and healthy food.

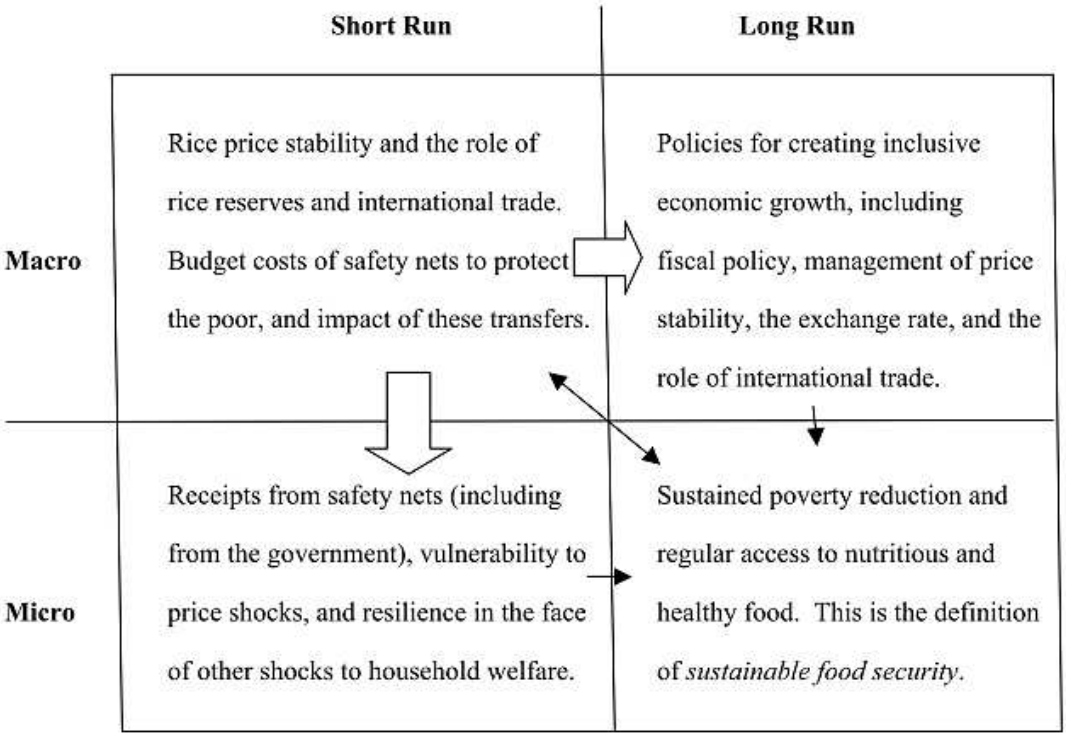


Figure 1: Basic framework to understand food security issues in Asia (From Timmer and Cabot, 2010, p. 4**)**

From an environmental point of view, rice agriculture is suffering from serious effects of climate change such as high temperatures, floods, salinity and droughts. Temperatures beyond critical levels do not only reduce the growth duration of the rice crop, but also increase spikelet sterility, reduce grain-filling duration, and enhance respiratory losses, resulting in lower yield and lower quality rice grains (Mohanty et al., 2013). Flood risks and salinity intrusions in rice-growing delta regions are predicted to increase with the sea level rise. Rising frequencies of extreme climatic events such as typhoons, droughts and heavy rainfall in monsoon climates will increase the occurrence of floods (GRiSP, 2013). Moreover, according to the Rice Almanac (GRiSP, 2013), the findings of simulations for major rice-growing regions of Asia show that yield may decrease by 7 % to 10 % for each 1^{o} C rise in temperature above current mean temperature at existing atmospheric carbon dioxide concentrations.

To tackle the dual challenges of food security and poverty alleviation, more rice needs to be produced at relatively low costs. That would assure fair profits for the rice producers and give the consumers an affordable supply of their main staple food. It is a long and challenging way on national and international scale to ensure food security. Food security is related to the two major concepts used in this thesis. The capacity of rice ecosystems to supply the provisioning ecosystem service food rice on the one hand, and the human well-being of the rice producers on the other hand, are two of the major factors influencing food security. However, food security is also considered as a part of human well-being (Dahl, 2012).

1.1.3 Rice Production and Consumption in Vietnam

Even though Vietnam has never been the largest, Vietnam has been amongst the top five rice producers in the world during the last ten years (FAOSTAT, 2014). In the year 2012, Vietnam has become the world's fourth largest rice producer (Figure 2) and one of the biggest rice exporters. During 17 years, from 1995 to 2012, the rice production of Vietnam has increased from 25 million tons to 43.44 million tons. This can be explained by the areal expansion for rice farming and higher yields of rice. The Rice Almanac (GRiSP, 2013) stated that rice yields, which were only 3.7 t/ha in 1995, increased to 5.3 t/ha in 2010. More modern rice varieties and increased fertilizer application accounts, additionally to the expansion of irrigated rice area, for the increase of rice yields in recent years.

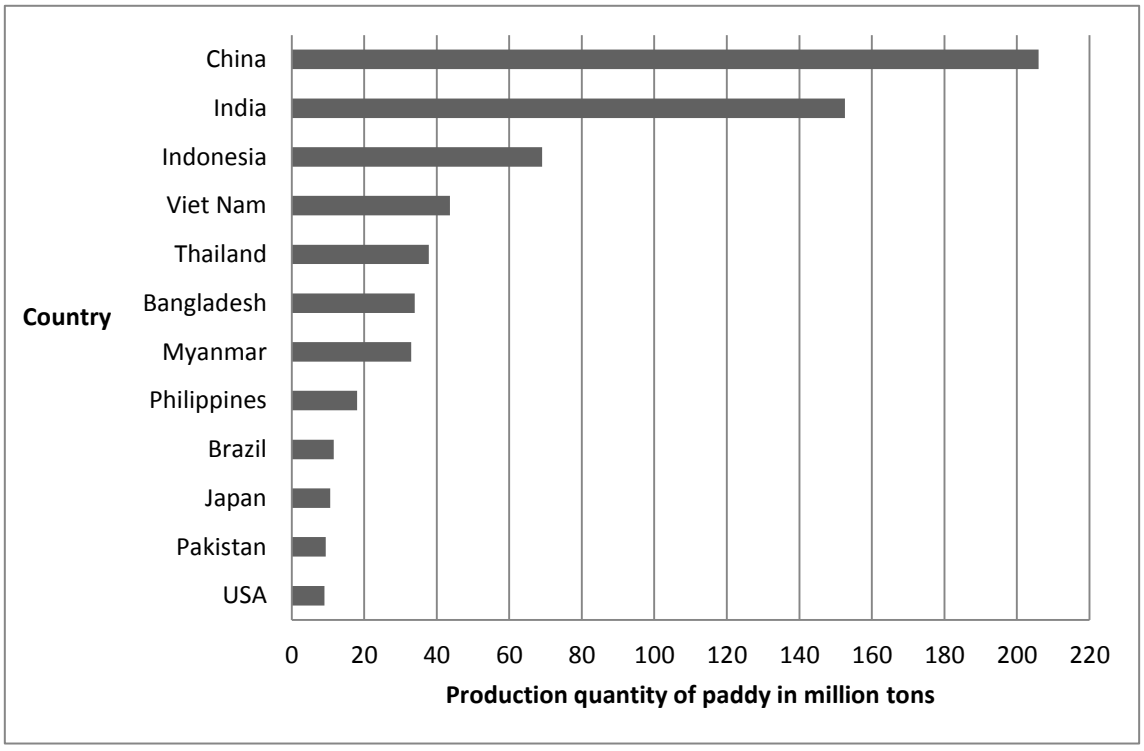


Figure 2: Leading rice producers in the world in 2012. (Data source: FAOSTAT, 2014)

Vietnam is still one of the leading countries in rice export. However, more and more arable land, including rice paddies, has been transformed into commercial land. The total area of paddy fields in Vietnam was 4.47 million hectares in 2000 and 4.13 million hectares in 2006, which constitutes a decrease of 316 thousand hectares in 6 years (Huynh and Ngo, 2010). According to the newest plan of the Ministry of Agriculture and Rural Development of Vietnam, in the year 2014, the area of rice paddy will be lessened 13000 ha, which will leave a total area of 3.8 million hectares of rice paddy in Vietnam (MARD, 2014). Hoang (2007) calculated that with each hectare of converted agriculture land, ten agricultural employees'

jobs were affected. However, the government believes that with the conversion of rice paddies into maize fields, the farmers are given a chance to gain more income (Dantri, 2014).

1.2 Ecosystem Services

Since the beginning of their existence on earth, humans have been benefiting from the complex goods and services that ecosystems supply. The term “ecosystem services” was first introduced in 1970 with examples such as insect pollination, fisheries and climate regulation in the “Study of Critical Environmental Problems” (SCEP, 1970; CH2M Hill, 2009). In 2003, when the Millennium Ecosystem Assessment clearly articulated the term “ecosystem services”, by defining them as the benefits people obtain from ecosystems (MA, 2003) , the concept became more popular. After that point, the number of publications referring to the term ecosystem services has increased rapidly (Fisher et al., 2009). However, the attempts of ecology and economics to standardize the definition and measurement of ecosystem services have mostly failed (Boyd and Banzhaf, 2007).

Nahlik et al. (2007) summarized the definitions commonly cited in the literature (Table 3). The various definitions show that experts and researchers working in different fields of study such as biology, geography, economy or social science, have their own views and understanding of the concept of ecosystem services. Nahlik et al. (2007) also showed an essential difference between definitions: with some, ecosystem services are the benefits themselves (MA, 2005; Costanza et al., 1997; Harrington et al. 2010), but to others, ecosystem services generate the benefits for humans (Daily, 1997; Boyd and Banzhaf, 2007).

Table 3: Definitions of ecosystem services and their sources commonly cited in literature (adapted from Nahlik et al. 2012).

Definition of ecosystem services	Citation
…"the benefits human populations derive, directly or indirectly, from ecosystem functions."	Costanza et al., 1997
…"the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life."	Daily, 1997
…"the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly."	de Groot et al., 2002
…"the set of ecosystem functions that is useful to humans."	Kremen, 2005
…"the benefits people obtain from ecosystems."	MA, 2005
…"components of nature, directly enjoyed, consumed, or used to yield human well-being."	Boyd and Banzhaf, 2007
…"the aspects of ecosystems utilized (actively or passively) to produce human well-being."	Fisher et al., 2009
…"a range of goods and services generated by ecosystems that are important for human well-being."	Nelson et al., 2009
…"benefits that humans recognize as obtained from ecosystems that support, directly or indirectly, their survival and quality of life."	Harrington et al., 2010
…"a collective term for the goods and services produced by ecosystems that benefit humankind."	Jenkins et al., 2010

Categories for ecosystem services have been developed in many different concepts. However the most commonly used classification divides ecosystem services into three categories: provisioning, regulating and cultural services. The Millennium Ecosystem Assessment (2005, p. 29) defined the categories:

- "**Provisioning services** are the products obtained from ecosystems such as food, fresh water, wood, fiber and genetic resources.
- **Regulating services** are defined as the benefits obtained from the regulation of ecosystem processes, including air quality maintenance, climate regulation, erosion control, regulation of human diseases, and water purification.
- **Cultural services** are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences."

The Millennium Ecosystem Assessment also included supporting services as the services necessary for the production of all other ecosystem services (MA, 2003). In the synthesis report of TEEB, "habitat or supporting services" was given as a fourth category of ecosystem

services, which highlight the importance of ecosystems to provide habitats for species and maintain biodiversity (TEEB, 2010).

Burkhard et al. (2012) introduced a definition of ecosystem services that also includes human inputs to the concept of ecosystem services. The definition of Burkhard et al. (2012, p. 2) declares: “Ecosystem services (ES) are the contributions of ecosystem structure and function – in combination with other inputs – to human well-being”.

1.2.1 Provisioning Ecosystem Service Food Rice

Provisioning services contain all physical products from ecosystems that human can take advantage of for nutrition, processing and energy purposes (Kandziora et al., 2013). Though there were many studies which developed and specified the concept of ecosystem services, the publications that mentioned the provisioning ecosystem service food rice were rare.

Natuhara (2013) identified and estimated the value of ecosystem services of rice paddies in Japan but only mentioned the functions of flood control, ground water recharge, soil erosion prevention, landslide prevention, organic waste treatment, local climate mitigation and recreation and excluded provision of food rice. Another study of Berg et al. (2012) stated that future production systems should not be optimized to only provide a single ecosystem service, such as rice, but designed to deliver a variety of interlinked ecosystem services, or bundles of services, such as rice, fish, pest control, and nutrient recycling.

1.3 Human Well-being

Human well-being is an equivocal concept, with a lack of a commonly accepted definition. It often has numerous and competing inference (McGillivray and Clarke, 2006). Terms, such as welfare, quality of life, living standards, life satisfaction or happiness, are often used synonymously with human well-being. In addition to this, human well-being is a complex notion and each study with a different approach has own definitions of human well-being.

In the following sections, the three concepts of human well-being that were used to develop this study are reviewed.

The Millennium Ecosystem Assessment (2003) stated that human well-being has multiple constituents, which include *basic material for a good life, freedom and choice, health, good social relations, and security*. Well-being is at the opposite end of a continuum from poverty, which has been defined as a “pronounced deprivation in well-being” (MA, 2005, p. 27). The constituents of well-being, which are based on experiences and perceptions of people, “are

situation-dependent, reflecting local geography, culture, and ecological circumstances" (MA, 2005, p. 27). The Millennium Ecosystem Assessment focused on the linkages between ecosystem services and human well-being and assessed the interactions between humans and ecosystems. More focus was put on the ecosystem services side and Millennium Ecosystem Assessment did not explain in detail, how to measure the linkages to human well-being.

1.3.1 National Accounts of Well-being and Happy Planet Index

In 2009, the New Economics Foundation (NEF) launched the National Accounts of Well-being (NEF, 2009). For NEF, well-being is best thought of as a dynamic process, emerging from the way in which people interact with the world around them (NEF, 2009). The model of National Accounts of Well-being, shown in Figure 3, was built to capture personal well-being and social well-being, demonstrating the important features of people's life experiences.

However, the idea of National accounts of Well-being only concentrated on the social and economic aspects of well-being and neglected the interaction between humans and ecosystems.

NEF also developed the Happy Planet Index, which puts more focus on the measure of sustainable well-being (NEF, 2012). The Happy Planet Index was brought into existence to manifest which countries are offering long and happy lives to their inhabitants, while at the same time, sustain the conditions to produce healthy and happy lives in the future (NEF, 2012).

The Happy Planet Index (NEF, 2012) is measured approximately by dividing the experienced well-being times the life expectancy by the Ecological Footprint

Equation 1: Happy Planet Index calculation (From NEF, 2012, p. 7).

$$Happy\ Planet\ Index\ \approx \frac{Experienced\ Well\text{-}being\ x\ Life\ Expectancy}{Ecological\ Footprint}$$

The NEF data of *Experienced Well-being* were taken from Gallup World Poll and the *Life Expectancy* data came from UNDP Human Development Report 2011. The *Ecological Footprint* data of 2008 were taken from Global Footprint Network for 142 countries and NEF estimated the *Ecological Footprint* for nine countries (NEF, 2012).

This method is more appropriate to inform the public than being used for scientific analyses, because the *Ecological Footprint* concept is not really accurate. Not every aspect of

sustainability is taken into account in the *Ecological Footprint* such as the availability of non-renewable resources, environmental management and harvest practices or land and ecosystem degradation (Ewing, 2010). Moreover, the *Ecological Footprint* is not a good measure of the ecological tradeoffs of land conversion, aquaculture production and the bioproductivity of the areas which are occupied by hydroelectric reservoirs and other infrastructure (Ewing, 2010).

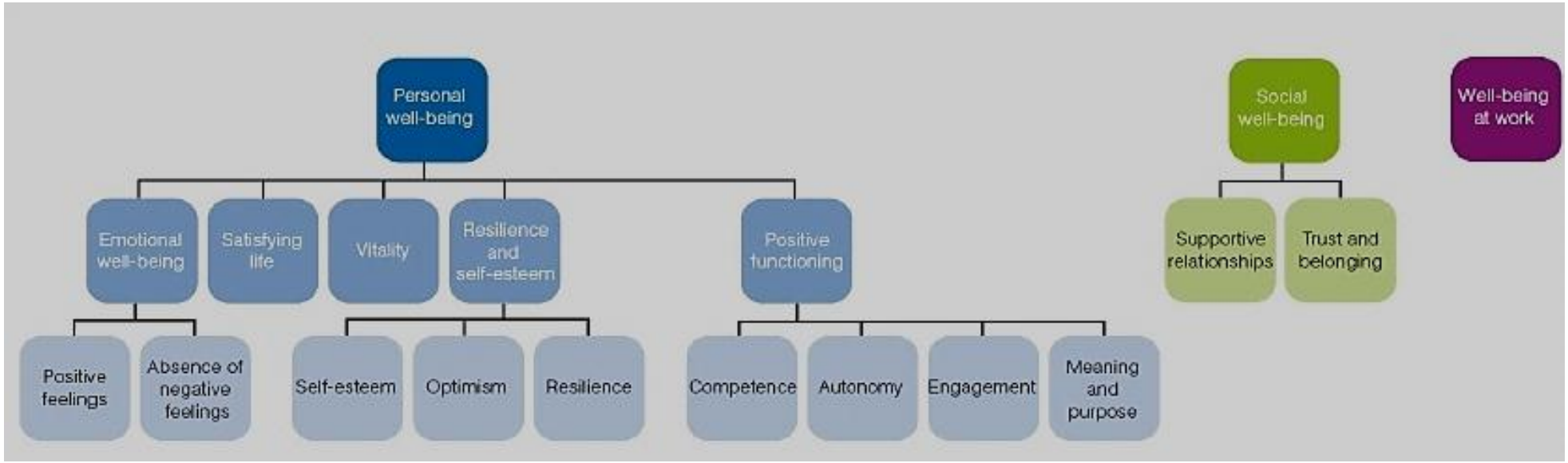


Figure 3: Indicator structure within the example national accounts framework (From NEF, 2009).

1.3.2 Quality of Life

Quality of Life is another approach to assess human well-being. However, Quality of Life is also seen as a vague and ambiguous concept to define (Galloway et al., 2006). According to Schalock (2000) there are more than 100 existing definitions of Quality of Life. Costanza et al. (2007) described Quality of Life as a general term which is often used to represent either, how well human needs are met, or the extent to which individuals or groups perceive satisfaction or dissatisfaction in diverse life domains. In the study of Costanza et al. (2007), the authors proposed an approach to Quality of Life that combined both subjective and objective components. An integrative definition of Quality of Life was proposed: "[Quality of Life is] the extent to which objective human needs are fulfilled in relation to personal or group perceptions of subjective well-being. Human needs are basic needs for subsistence, reproduction, security, affection, etc."(Costanza et al, 2007, p. 269). The relation between the satisfaction of human needs and overall subjective well-being is affected by the importance given to each of the human need (Figure 4).

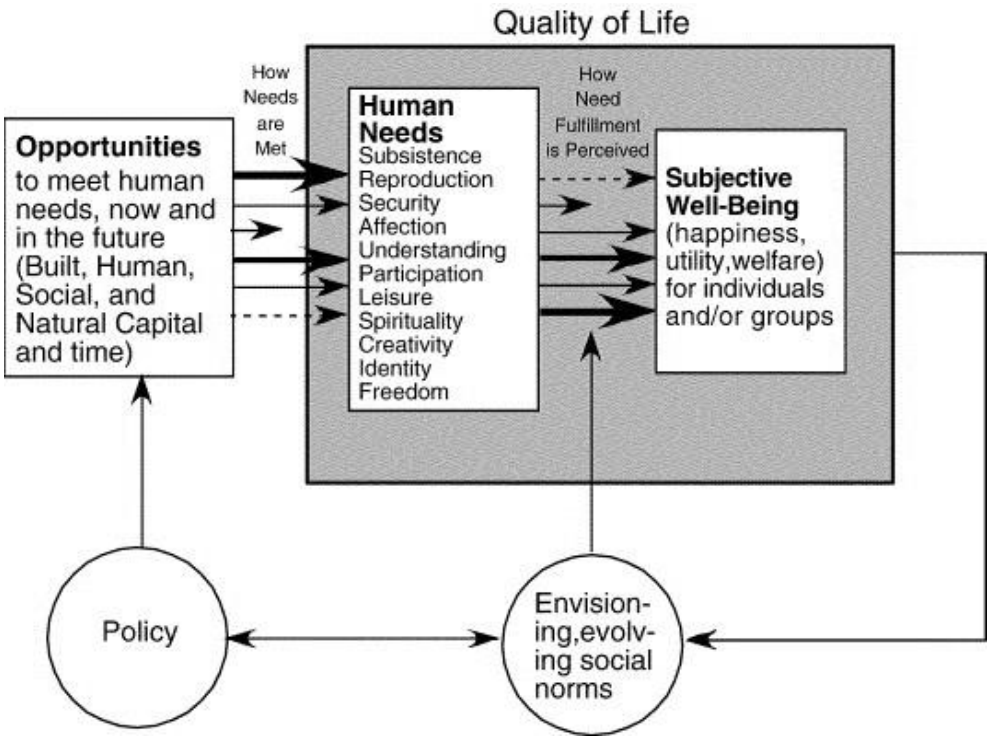


Figure 4: Quality of Life as the interaction of human needs and the subjective perception of their fulfillment, as mediated by the opportunities available to meet the needs. (From Costanza et al., 2007)

It was stated that "by combining so called *subjective* and *objective* measures into a single Quality of Life concept, we get a more realistic picture of the important inputs and variables

for improving Quality of Life. The general tool provides a framework for further research." (Costanza et al., 2007, p. 276).

According to Stiglitz et al. (2009, p. 216), "Quality of Life includes the full range of factors that make life worth living, including those that are not traded in markets and not captured by monetary measures." In order to measure Quality of Life, subjective well-being and objective conditions and opportunities have to be covered. Moreover, Stiglitz et al. (2009) mentioned that it is crucial to measure the Quality of Life not only on country average level but also take individual experiences into account. Inequality in each dimension of Quality of Life needs to be assessed and is considered as an important component of the Quality of Life measurement (Stiglitz et al., 2009).

1.3.3 OECD How's Life? Report

The *How's life?* report is a part of the OECD Better Life Initiative as a first attempt at the international level to go beyond the conceptual stage and to present a large set of comparable human well-being indicators for OECD countries and, to the extent possible, other major economies (OECD, 2011).

Figure 5 presents the conceptual framework of the OECD to define and measure human well-being. The framework distinguishes current well-being and future well-being. Current human well-being can be measured by the outcomes of two domains including 11 dimensions: *material living conditions* (income and wealth, jobs and earnings, housing) and *quality of life* (health status, work-life balance, education and skills, social connections, civic engagement and governance, environmental quality, personal security, subjective well-being). Future human well-being is measured by analyzing the key resources that determine human well-being over time. These resources can be measured through indicators of different forms of "capital".

The OECD (2013) framework to measure current human well-being has four distinctive features:

- It emphasizes on people as focusing on people themselves is important and there might be differences between the economy-wide assessment and the human well-being experience of individuals and households in a country.
- It emphasizes on outcomes rather than inputs or outputs of human well-being.
- It analyzes the distribution of human well-being in the population across different age groups, genders and individuals' socio-economic backgrounds.
- It considers both subjective and objective human well-being.

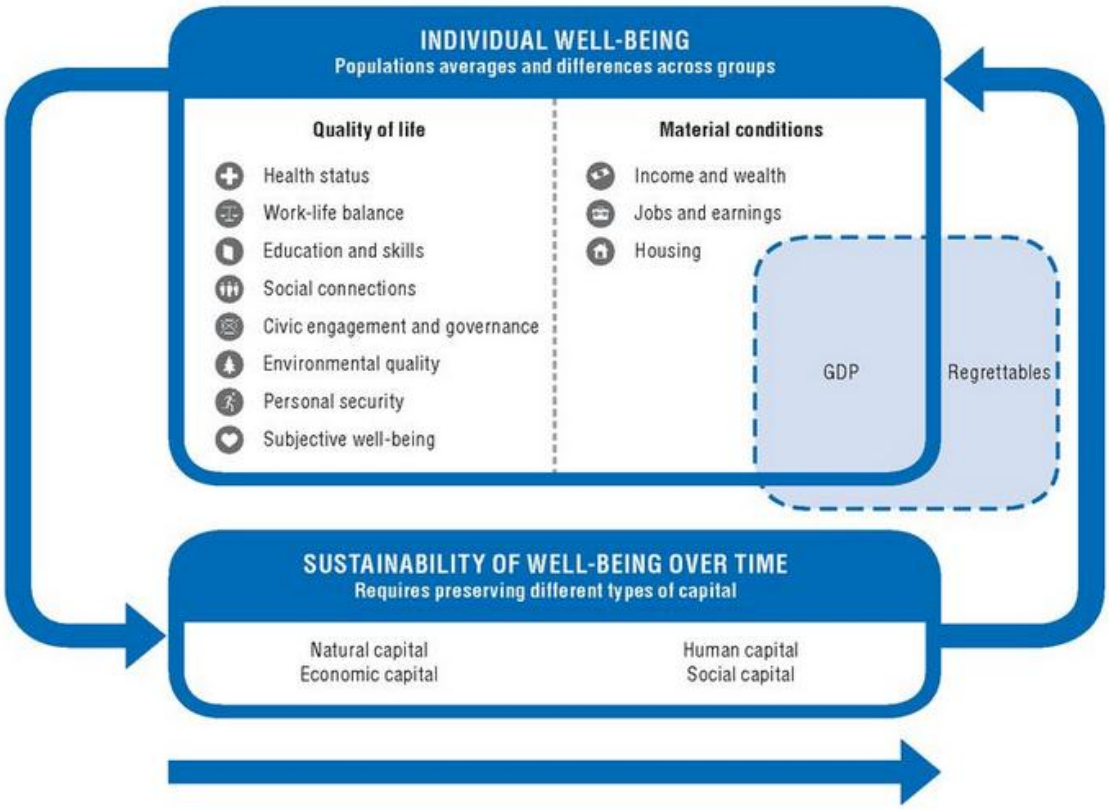


Figure 5: The OECD conceptual framework of human well-being (From OECD, 2013).

1.4 Linkages of Ecosystem Services and Human Well-being

Human well-being and its progress toward sustainable development are vitally dependent upon the earth's ecosystems (MA, 2003). That is why understanding the relations between human well-being and ecosystem services is crucial. Does the degradation of ecosystems lead to a decrease of human well-being as many people suppose? Are degradations of the majority of ecosystems the result of steady gains in human well-being at the global scale as the Millennium Ecosystem Assessment (2005) stated? What is the real pattern of this connection? Raudsepp-Hearne et al. (2010) asserted that although there is already a good understanding of the negative impacts of human activities on biodiversity, natural capital, and the biosphere, humans have only a weak understanding of the consequences of changes in the earth system to human well-being. In this subchapter, an overview of two concepts that are closely related to this study will be given: the Millennium Ecosystem Assessment (MA, 2003) and the concept presented by Busch et al. (2011). The following sections will give an introduction to indicators and their use as an instrument to measure ecosystem services and human well-being.

1.4.1 Millennium Ecosystem Assessment

The MA (2003 and 2005) highlighted the role of ecosystem services in enabling improvements in human welfare. The MA also introduced ecosystem services as necessary conditions for poverty reduction and for achieving the Millennium Development Goals (Abunge et al., 2013). The MA examines how changes of ecosystem services influence human well-being. Changes in ecosystem services (provisioning, regulating and cultural services) affect human well-being through impacts on the constituents of human well-being. Constituents of human well-being are *security, basic material for good life, health* and *good social relations* (MA, 2003). *Freedom of choice and action* does not link directly to any of the ecosystem services, but it is influenced by the other constituents of human well-being and is a precondition to achieve those components of human well-being.

Figure 6 depicts the strength of linkages between categories of ecosystem services and components of human well-being that are commonly encountered. Furthermore, it includes indications of the extent to which it is possible for socioeconomic factors to mediate the linkages. "The strength of the linkages and the potential for mediation differ in different ecosystems and regions. In addition to the influence of ecosystem services on human well-being depicted here, other factors — including other environmental factors as well as economic, social, technological, and cultural factors—influence human well-being and ecosystems are in turn affected by changes in human well-being" (MA, 2005, p. 28). However, there was no description given by the MA of the method how to determine and measure the linkages.

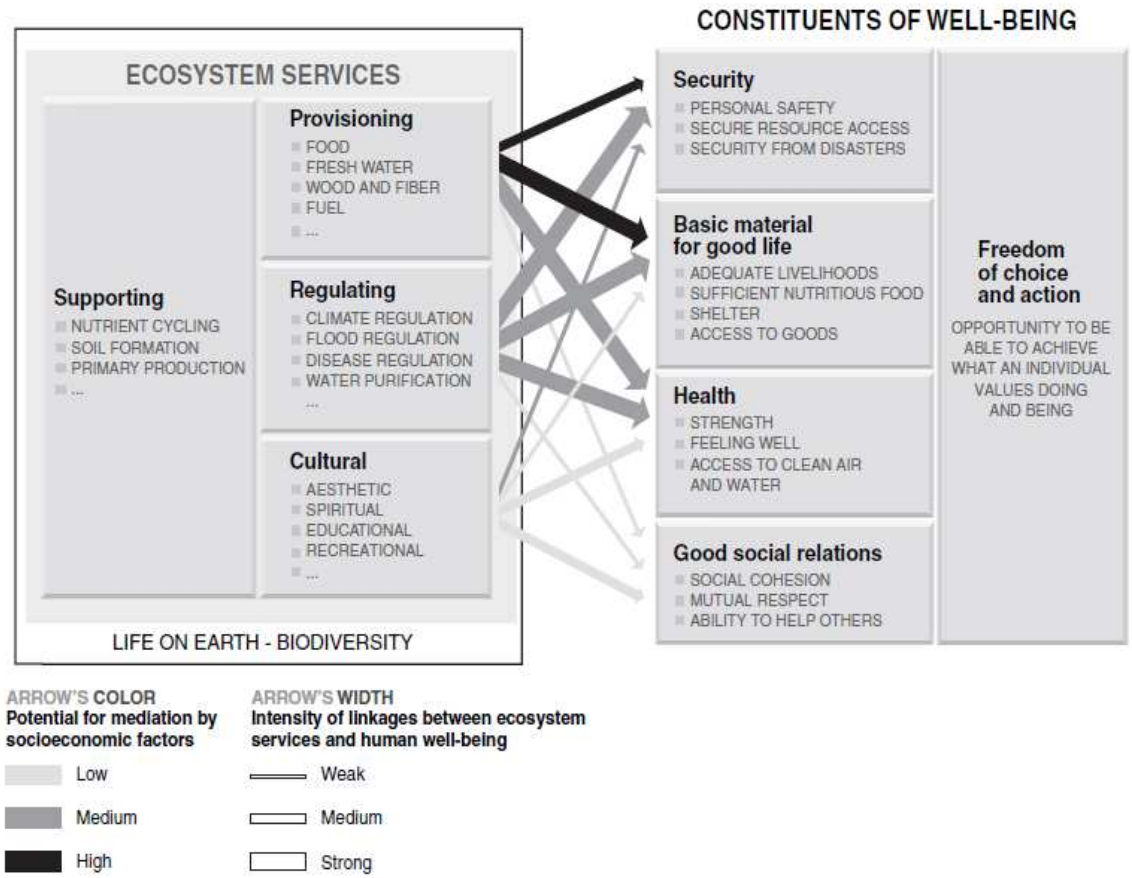


Figure 6: Conceptual linkages between ecosystem services and human well-being (from MA, 2005).

1.4.2 Linkages between Marine Ecosystem Services and Human Well-being (Busch et al. 2011)

Busch et al. (2011) examined the impacts of offshore wind farming on ecosystem services by identifying six ecosystem services that are directly affected by offshore wind farming at a conceptual stage. Following that the study developed an approach to investigate the effects on human well-being. Busch et al. (2011) selected twelve determinants of human well-being, including objective and subjective determinants of human well-being, which allowed the assessment of specific influences of certain ecosystem services. The links between the possible changes in the identified ecosystem services and the impacts of them on the twelve determinates of well-being were determined in a qualitative way. Busch et al. (2011) showed that the methodology of the study allows a verification of the effects of ecosystem services changes on different dimensions of human well-being. This study from Busch et al. (2011) forms and defines a method to verify specific relations of ecosystem services to dimensions of human well-being.

1.4.3 Indicators in Ecology

Indicators are effective tools to serve several purposes. They can be used to assess the condition of the environment or to monitor trends in conditions over time (Dale and Beyeler, 2001). Additionally, they can provide early warning signals of changes in the environment, and they can be used to diagnose the cause of an environmental problem (Dale and Beyeler, 2001). However, according to Heink and Korawil (2010), indicators are frequently used but none of the available definitions covers the complete meaning of the term.

A systematic overview of the definition of indicators from the aspects of ecology and environmental planning was given by Heink and Kowarik (2010). The indicator term was used as a synonym for "*indicans*", which means a "measure or component from which conclusions on the phenomenon of interest (the *indicandum*) can be inferred" (Heink and Kowarik, 2010, p. 584). Indication could be understood as the reflection of an *indicandum* by an indicator.

Heink and Kowarik (2010) gave a proposal for the definition of indicator:

"An indicator in ecology and environmental planning is a component or a measure of environmentally relevant phenomena used to depict or evaluate environmental conditions or changes or to set environmental goals."(Heink and Kowarik, 2010, p. 590).

In the study of Kandziora et al. (2013), the authors used the following indicator definition:

"Indicators are variables which provide aggregated information on certain phenomena. Indicators are selected on the base of specific management purposes, with an integrating, synoptical value, which (in the optimal case) shows the difference between existing states and aspired target situations. Indicators are also comprehended as depictions of qualities, quantities, states or interactions that are not directly accessible." (Kandziora et al., 2013, p. 54).

1.4.4 Indicators for Ecosystem Services

Indicators are used to track and convey trends of ecosystem services (Layke et al., 2012). It is important to be aware if the services are being sustained or lost (Layke et al., 2012). Moreover, the design of policies should ensure the flow of services to support human well-being and maintain biodiversity (Layke et al., 2012). That explains why indicators attract attention and interest of a variety of users from international to national and local levels (UNEP-WCMC, 2011).

The study Developing Ecosystem Service Indicators of the Convention on Biological Diversity (CBD) of the year 2011 reviewed the existing ecosystem services indicators and metrics (UNEP-WCMC, 2011). It was mentioned that the development of robust indicators is often hindered by a lack of information and data (UNEP- WCMC, 2011). The majority of indicators found focus on regulating and provisioning ecosystem services. There are 29 indicators illustrating provisioning ecosystem services food, addressing capture fisheries, crop and livestock production and wild foods (UNEP- WCMC, 2011). The publication of Kandziora et al. (2013) also proposed three potential indicators for crop provisioning ecosystem services: harvested crops, net primary production and yield.

1.4.5 Indicators for Human Well-Being

In recent years, high expectations have been raised for the ability of indicators to support decisions and policies which aim to improve human well-being (Rinne et al., 2013). Many human well-being indicators have been developed with the aim to capture the multidimensional aspects of human well-being in a single number (MA, 2005, p. 54).

Smith et al. (2013) made a review of existing measures of well-being, which included 799 indicators in 157 different dimensions of human well-being. The results of Smith et al. (2013) presented in Table 4 show that health, living standards, social cohesion, education, and safety and security are the dimensions of human well-being which are characterized by a high number of indicators.

Table 4: Human Well-Being focal areas ranked by the number of indicators in Smith et al. (2013) (From Leisher et al., 2013, p. 1004).

Focal area	Number of indicators
Health	112
Living standards	79
Social cohesion	68
Education	67
Safety and security	61
Others	54

Due to the high number of available measurements for human well-being, this study took the *How's Life?: Measuring Well-being* report (OECD, 2011) as the main guideline regarding the human well-being assessment. According to the OECD (2011), at first, indicators for measuring well-being must be chosen in a way that it can suitably capture the dimensions of human well-being. The OECD puts great efforts into choosing available indicators that are conceptually relevant to measuring human well-being across the population (OECD, 2011). In general, the OECD (2011) distinguished between two types of indicators: headline indicators and secondary indicators. Headline indicators are indicators that are determined to be of sufficiently good quality and used for monitoring human well-being in a long time period and across countries. Secondary indicators provide complementary evidence but are limited in international comparison.

The selection of indicators in *How's life?* (OECD, 2011) was based on international standards in measurement including: policy relevance; quality of the underlying data; comparability of the concepts and survey questions used; and frequency of compilation. The aim of this indicator selection was to make sure that the indicators:

- "Have face validity, i.e. the capacity to capture what is intended to be measured;
- Focus on summary outcomes, i.e. on relatively broad achievements that can be easily understood;
- Are amenable to change and sensitive to policy interventions, which is important from the perspective of improving the design of policies that bear on well-being;
- Are commonly used and accepted as well-being indicators within the statistical and academic communities;
- Ensure comparability across countries. Comparability is ensured when concepts and definitions follow internationally agreed standards and the surveys/instruments from which data are collected are based on a harmonized questionnaire and similar implementation design;
- Ensure maximum country coverage (which is due to the aim of the OECD report) and
- Are collected through a recurrent instrument, which is important for monitoring changes in well-being over time." (OECD, 2011, p. 22)

Most of the indicators in the *How's life?* report have full face-validity, while there are a few others only meeting this criterion partly. Most indicators can be influenced by policies and all of them change over time (OECD, 2011). However, it can be seen that the current choice of indicators is a good approximation of the ideal concepts. In the future, the possibility of

changes to the indicator selection is available as better statistics might become available (OECD, 2011).

1.5 Research Agenda

The concept of ecosystem services (Subchapter 1.2) is widely popular amongst scientists (Müller and Burkhard, 2012, Seppelt et al. 2011). There is a high potential to improve the management practice of ecosystems using the concept of ecosystem services, which can advance the benefits for humans and nature (Daily et al., 2009). Even though ecosystem service literature has been expanding massively in recent years, the application aspect of the concept in rice paddy ecosystems has not been considered much. As it was explained in Subchapter 1.1, rice plays an important role in feeding the world and has formed an important part of the culture in many regions of Asia. Therefore, this work wants to investigate the provisioning ecosystem service food rice supply in two study regions in Vietnam. Understanding the human well-being (Subchapter 1.3) of rice farmers is very important for a better analysis of the human side of the rice production system. The well-being assessment of the work concentrates on rice farmers, because they have direct benefits from the rice they produce with the help of the rice paddy ecosystems. Furthermore, investigating the two concepts of ecosystem services and human well-being in a rice paddy context has not been done before. It promises a deeper knowledge of the processes taking place in rice production. This pilot study will develop and test an indicator set that covers provisioning ecosystem service food rice supply on the one hand and human well-being of rice farmers on the other hand. The aim is to uncover trends of human well-being and rice provisioning in order to understand the linkages between the two. Such analysis will allow the development of recommendations for better management practices that will ensure a more sustainable rice production in the future.

The work will be conducted in the frame of the LEGATO project (Subchapter 2.1) and focus on three research questions:

- What is the ideal indicator set to indicate human well-being and the provisioning ecosystem service food rice in the study regions?
- What are the main trends and patterns of human well-being and the provisioning ecosystem service food rice?
- Which are the linkages between the provisioning ecosystem service food rice and the different dimensions of human well-being?

2. Methods

2.1 LEGATO Project

LEGATO[1], which stands for "**L**and-use intensity and **E**cological En**G**ineering- **A**ssessment **T**ools for risks and **O**pportunities in irrigated rice based production systems", is an international research project with different institutes in Germany, Philippines, Vietnam and other countries, funded by the German Federal Ministry of Education and Research (BMBF). The overall goal of the project is the elaboration and testing of generally applicable principles within the frame of ecological engineering - an emerging discipline, concerned with design, monitoring and construction of ecosystems (Settele et al., 2013). The focus research areas of LEGATO are in Southeast Asia: Vietnam (Lao Cai province in the Northwest mountain region, Hai Duong and Vinh Phuc provinces in the Red River Delta and Tien Giang province in the Mekong Delta) and the Philippines (Ifugao, Nueva Ecija, Laguna). The ecosystem functions and services that the regions supply to the agricultural systems will be quantified and interdependencies will be analyzed. Local as well as regional land use intensity and biodiversity, and the possible impacts of climate change and land use change are the main focuses. The supporting ecosystem services (MA, 2005) are regarded as ecosystem functions and the project is dealing with three ecosystem services categories: Provisioning, Regulating and Cultural Services.

According to the project description (LEGATO, 2011), LEGATO plans to investigate the interactions between rice ecosystems, the landscapes and the socio-cultural perceptions. Another aim is to quantify and assess the uncertainty of the current and future dependencies of ecosystem functions and ecosystem services on the land use intensity, biodiversity, climate and socio-economic constrains. The LEGATO project investigates three strands of ecosystem function and ecosystem services, including nutrient cycling and crop production, crop related biocontrol and pollination and agricultural landscape related cultural identity and aesthetics. Indicator sets which investigate ecosystem functions and ecosystem services through monetary and non-monetary methods will be developed. The indicators will be tested and improved in the research regions and compared across nations. Guidelines for decisions makers and farmers are developed by the LEGATO project. The implementation of the guideline will be tested to enhance ecosystem services supply. The LEGATO project also plans to design socio-economic analytical frameworks and tools in order to promote the practices of advanced land management.

[1] http://www.legato-project.net/

The planned core achievement will be the development of a set of guidelines for "optimizing ecosystem functions and services given the local socio-cultural conditions and their stabilization under future climate and land use change, which will particularly affect South and Southeast Asia" (LEGATO, 2011, p. 6). LEGATO will also consider the ecological engineering potential for crop productivity increases and diversification and test its implementation across the regions (LEGATO, 2011).

This thesis focuses on two of the four LEGATO regions in Vietnam, i.e. Lao Cai (VN_3) and Tien Giang (VN_4). It was conducted within the work package number 4.2 regarding the development of indicators of LEGATO project. The overall objectives of this work package are (LEGATO, 2011):

- Identification of suitable indicator sets in order to characterize the state of the environment and related socio-economic and cultural factors;
- Quantification of the indicators based on the results of other work packages;
- Integration of LEGATO results into an interdisciplinary indicator framework system.

2.2 Research Areas

The research areas of the LEGATO project concentrate on seven regions: four in Vietnam and three in the Philippines, each region with a 15 km x 15 km area. Those regions were chosen according to similar biophysical gradients from mountainous to lowland areas in Vietnam and the Philippines. In the mountainous areas, land use intensity is frequently lower with generally higher structural and cultural diversity. In the lowland areas land use intensity is often higher combined with medium until low structural ecosystem and cultural diversity. This study was carried out in the two regions: Lao Cai (VN_3) and Tien Giang (VN_4).

Figure 7: Geographic location of LEGATO regions. Philippines (Luzon Island): PH_1: Laguna; PH_2: Nueva Ecija; PH_3: Ifugao. Vietnam: VN_1: Hai Duong; VN_2: Vinh Phuc; VN_3: Lao Cai; VN_4: Tien Giang. (From LEGATO, 2013).

2.2.1 Sa Pa, Lao Cai (VN_3)

Lao Cai was re-established in 1991 from the Hoang Lien Son province and is situated in the Northwest region of Vietnam, sharing a border with the Yunnan province of China (Lao Cai Government Portal, 2008a). The total area of Lao Cai is 6384 km^2 (GSO, 2012). In 2012, Lao Cai had a population of 646800 people and the population density was 101 persons per km^2 (GSO, 2012). The area of arable land in Lao Cai is 300 km^2 of which around 30 % are terraces. With 2.44 % of the total area of Vietnam, Lao Cai is the 19th biggest province of Vietnam (Lao Cai Government Portal, 2012b). Lao Cai is listed as a relatively poor province of Vietnam. In 2009, the poverty rate was 56.77 % of the province population (GSO, 2010). The province could not produce enough food for the population and received subsidies from the government (500 tons of rice in 2011) (IPAM, 2012). The Government of Lao Cai is also active in implementing different policies to increase agricultural production, especially rice. For example, the price of hybrid rice seeds is subsidized and the farmers are instructed to apply more up-to-date techniques in the practice of farming (IPAM, 2012).

This study was conducted in Sa Pa, a district of the Lao Cai province. The Sa Pa district consists of Sa Pa town and 17 other communes (Hau Thao, Ban Phung, Ta Phin, Nam Sai, Thanh Pha, Sa Pả, Lao Chai, Trung Chai, San Sa Ho, Thanh Kim, Ban Ho, Su Pan, Suoi Thau, Ta Van, Ban Khoang, Ta Giang Phinh and Nam Cang). The original name of Sa Pa is Sa Pả, which means the sand yard in Mandarin (Lao Cai Government Portal, 2008b). The “sand yard” is where the

former market of locals often took place. After the arrival of the French in 1903, the name Sa Pả was changed to Sa Pa as they could not pronounce the tone and the change was kept since then (Lao Cai Government Portal, 2008b). Today, Sa Pa is known as a favorite tourist destination because of its spectacular landscape, including the rice terraces and the amenities of traditional cultures of the local ethnic groups (Vu and Makoto, 2010; Duong, 2006). Farmers in Sa Pa started to cultivate rice on terraces in the 18th century. Rice terraces have been transferred as heritage from ancestors to descendants (IPAM, 2012)

The total area of the Sa Pa district is 683.29 km^2, accountings for 8 % of the area of the Lao Cai province (GSO, 2010). The terrain of Sa Pa is typical for the Northern mountainous areas of Vietnam with steep slopes (the average is 35° to 40^o and could be up to 45^o at some places) and rugged terrain (Lao Cai Government Portal, 2012c). Situated at the East of the Hoang Lien Son mountain range, the average height of Sa Pa is from 1200m to 1800m, relief sloping and the steepness decrease in the direction from West-Southwest to Northeast. The highest peak is the Fansipan (3143m above sea level) and the lowest point is Suoi Bo (400m above sea level) (Lao Cai Governmental Portal, 2012c).

Sa Pa has a subtropical highland climate with cool summers and much rain from May to October, and cool winters with little rain from November to April. The average temperature of Sa Pa is 15.4^{o}C, with 18°C to 20^{o}C in summer and 10°C to 12^{o}C in winter. The maximum temperature is 33^{o}C in April and the minimum temperature is 0^o C in January (sometimes it can be -3^{o}C in winter) (Lao Cai Governmental Portal, 2012c).

In 2009, the total population of the Sa Pa district was 53549 people, of which 44574 were living in rural areas (Central Population and Housing Census Steering Committee, 2010). Hmong are the biggest ethnic group accounting for 51.65 % of the population of Sa Pa. The other groups are Yao (Dao), Kinh, Tay, Day and Xa Pho which make up 23.04 %, 17.91 %, 4.74 %, 1.36 %, and 1.06 % of the population (Central Population and Housing Census Steering Committee, 2010).

The Kinh people came to Sa Pa mainly due to business purposes (Michaud and Turner, 2000). They only live in Sa Pa town and account for 15 % of the town population. The other ethnic groups can be found in the different communes and in Sa Pa town. They mostly earn a living from agriculture, forestry and handicrafts. Today, with the development of tourism, one large share of their income also comes from providing services to tourists, such as local homestay, tour guidance or sales of local specialties and traditional textiles (Dinh and Santasombat, 2013).

Figure 8*:* Rice terraces in Sa Pa (photos taken by the author on 13.04.2013 in Trung Chai and Ta Phin, Sa Pa).

2.2.2 Cai Lay, Tien Giang (VN_4)

Tien Giang is a province in the Mekong delta region in southern Vietnam, 70 km south of Ho Chi Minh City. The total area of Tien Giang is 2481.8 km^2 and the province has a coast line of 32 km (GSO, 2012). Along the coast, there are thousand hectares of mudflats which are used for aquaculture (Tien Giang Government Portal, 2014c). The interlaced river system of Tien Giang with the Tien river, Vam Co Tay river, Cho Gao canal, and the Nguyen Van Tiep canal links the provinces of the Mekong river delta with Ho Chi Minh City. It is also the gateway of the provinces on the Tien river banks and Cambodia to the East Sea (Tien Giang Government Portal, 2014b).

Tien Giang has a tropical monsoon climate with high humidity. The wet and dry seasons are distinct from each other: the dry season begins from December and the wet season starts in May. The annual average temperature is 27°C (Tien Giang Government Portal, 2013).

Most soils in the Tien Giang province are alluvial soils, alkaline soils and alum soils. The area of alluvial soils, which is ideal for agriculture, is 1254.3 km^2 (50 % of the total area) (Invest in Vietnam Portal, 2013). Tien Giang is known as the rice granary of Vietnam as 47.68 % of its arable land was used for rice cultivation in the year 2000 (Tien Giang Government Portal, 2014b). Tien Giang also has a vast area of tropical fruit trees such as mango, durian and rambutan.

Tien Giang is famous for tourism with many cultural-historical monuments, such as Oc Eo, Go Thanh cultural vestige (I-VI century B.C.), the historical monuments in Rach Gam, Xoai Mut, Ap Bac; temples and pagodas or imperial tombs (Tien Giang Government Portal, 2014c).

The study was conducted in the Cai Lay district of the Tieng Giang province. The Cai Lay district consists of one town and 27 communes. The total area of Cai Lay is 441.3 km^2, of which

agricultural land occupies 81.5 % (Cai Lay Government Portal, 2013). Taking the Highway 1A as a boundary, the northern area is lowlands, suffering from salt-contamination from brackish river water several months annually (Tien Giang Government Portal, 2014a). Whilst, the fertile alluvial soils with the accretion of the Tien River are found mostly in the southern parts of Cai Lay (Tien Giang Government Portal, 2014a). Beside paddy fields, Cai Lay is also known for its fruit plantations. Thanks to the fertile land and abundant water supply from the canal systems, the fruit trees could grow in under ideal conditions. Vast plantations with savory fruits, such as durian, orange, mandarin, rambutan and longan, not only create additional earnings for the farmers, but also provide a promising opportunity for eco-tourism (Tien Giang Government Portal, 2010).

Cai Lay had a population of 305906 people in 2009, making up 18.3 % of Tien Giang's total population (Central Population and Housing Census Steering Committee, 2010). Most of the population in Cai Lay belongs to the Kinh ethnic group. Additionally, there is a small group of Hoa and Khmer (Tien Giang Government Portal, 2014a). However, there was no data showing the exact percentage of the ethnic groups in Cai Lay.

Figure 9: Rice fields in Tien Giang (photos taken by the author on 23.05.2013 in Cai Lay, Tien Giang).

2.3 Indicator Selection

The following section will explain the development of the indicator framework for the field study in the research regions. There was no comparable research covering the topic of the linkages between human well-being and the provisioning ecosystem service food rice available in the published literature. Therefore, the two studies mentioned before (Busch et al., 2011 and OECD, 2011) were used as pioneer guidelines for the choice of indicators. The following paragraphs explain the selection of indicators for human well-being and the provisioning ecosystem service food rice in more detail.

2.3.1 Indicators for Human Well-Being

As mentioned in the introduction chapter, there are various definitions of human well-being as different studies research about different aspects of human well-being. For the purpose of this study, it was decided to analyze human well-being within the dimensions of *economic well-being, social well-being, health, personal well-being and environmental quality*, adapting from Busch et al. (2011) and the *How's life* report of the OECD (2011). The specific categories that were attributed to the dimensions were also defined (Table 5).

The next step was to define the target group of the study. To serve the purpose of the study, investigating the relations of the provisioning ecosystem service food rice and human well-being, it was decided to focus on rice farmers as the target population. Since the rice farmers take direct advantage of the provisioning ecosystem service food rice, they are most likely showing a linkage between the provisioning ecosystem service food rice and human well-being. The term "rice farmer" in this study is defined as the farmers who directly take part in the process of rice production from seedling to harvesting.

In order to see trends of the indicators, it was decided to look at each indicator at three different points of time: present (2012), past (2002) and future (2022). Thereby, also changes in the correlation between the provisioning ecosystem service food rice and human well-being could be tracked. The time scale was set to ten years, as a decade is long enough to see a change but not too long, so that the farmer can still remember the situation of ten years ago or imagine and anticipate what might happen in ten years. The indicators were chosen based on their relevance in the situation of Vietnam and the possibility of data collection. Moreover, they should be representative of the dimensions and categories that they indicate. The number of indicators was confined to an achievable number in the limited time available for the study. The set of indicators shown in Table 5 is the temporarily optimal version that was to be tested in the research regions.

Table 5: Proposed indicator set for human well-being of rice farmers in the research areas.

No	Dimension	Category	Definition (adapted from Busch et al. 2011 and from OECD 2011)	Indicator	Parameter Unit	Data Sources
1	Economic well-being	Income	Disposable income; that is, the income available to individuals for meeting their respective needs. The material basis available to each individual for participating in social life.	Average annual income of farmers	VND	Farmer survey, statistical data
2				Savings rate of average annual income	%	
3				Share of average annual income from rice	%	
4		Employment	Diversity and security of available agricultural jobs within the region, linked to the overall regional employment/unemployment ratio.	Employment rate	%	Statistical data
5				Share of employees working in rice production	%	
6	Social well-being	Demography	Dynamic changes of population numbers and overall social composition.	Population structure according to age groups	%	Statistical data
7				Ratio of women/men working in rice production	-	
8				Net migration per 1000 inhabitants	persons/year	
9		Education	Assess to formal education for the rice farmers and their children in the region.	Farmers finished secondary school	%	Farmer survey
10				Farmers finished high school	%	
11				Farmers' children visiting high school	%	
12	Health	Nutrition	Availability and quality of locally produced rice and rice products.	Share of locally produced rice supply in the region	%	Official sources
13		Infrastructure	Access to health infrastructure and the overall status of health infrastructure within the case study area.	Number of doctors per 1000 inhabitants	-	Statistical data
14				Number of hospital beds per 1000 inhabitants	-	
15	Personal well-being	Personal well-being	Subjective determinants of quality of life.	Personal satisfaction and happiness	scale from 1-10	Farmer survey
16		Work and life balance	The ability to combine work, family commitments and personal life.	Average working time during busy period	hours/day	
17				Average working time during other periods	hours/day	
18				Time spent for leisure and personal care	hours/day	
19	Environmental quality	Environmental quality	The health of the physical environment, focusing on pollution aspects.	Satisfaction with the quality of air	scale from 1-3[2]	Farmer survey
20				Satisfaction with the quality of water	scale from 1-3[2]	

[2] 1 = not satisfied, 2 = satisfied, 3 = very satisfied

2.3.2 Indicators for Ecosystem Service Provisioning Food Rice

The indicators for the provisioning ecosystem service food rice were selected according to different criteria. They should be able to illustrate the rice production activities in the area, for example the *yield of paddy* per season, *number of harvests* in one year in each region or *percentage of machinery use*. These indicators also enable a comparison of rice production in different areas as each region has its own natural conditions and cultivation methods.

The indicator *yield of paddy* directly indicates the productivity of each region. The term paddy refers to the unmilled stage of rice after threshing. *Yield of paddy* is a popular indicator which can be found in many statistical data sources. Another method to measure the rice yield is to take the rice samples directly from the fields and measure them after drying the samples in the oven. This method was used by the LEGATO project scientists to investigate the biomass production of the LGATO sites.

The overall idea of the indicator set is to include the numerous human inputs to the rice ecosystem to indicate the inputs that are needed to supply the provisioning ecosystem service food rice. With the two indicators export of rice from the region and import of rice to the region, it was planned to measure the demand and supply balance of the areas. Table 6 shows the indicators which were chosen to measure the provisioning ecosystem service food rice in Lao Cai and Tien Giang.

Table 6: Proposed indicators for the provisioning ecosystem service food rice and parameters for their quantification.

Indicator	Parameter Unit
Yield of paddy	tons/ha/season
Number of harvests	1 to 3 per year
Fertilizer use	kg of NPK per ton of rice output
Machinery use	hours of work per ton of rice output
Labor input	hours of work per ton of rice output
Export of rice from the region	tons/yr.
Import of rice to the region	tons/yr.

2.4 Questionnaire

The questionnaire was designed after the indicator selection. A cover letter to the interviewees was included in the questionnaire and the questions were related to 4 different topics: *environmental quality*, *rice provisioning*, *economic well-being* and *personal well-being*. The questionnaire was developed in English and later on translated into Vietnamese. First, the questions were developed based on the selected indicators of the provisioning ecosystem service food rice and human well-being considering the information which needed to be collected. Some of the questions concerning human well-being were also adapted from the *How's life* report (OECD,2011). The questions were asked in three different time periods: Past, Present and Future with the timescale of ten years. In order to collect quantitative data, most of the questions were close-ended with rating scales and inverted funneling questions (Barribeau et al., 2012). The purpose of inverted funneling questions is to ask the respondent specific and closed-end questions first and then move to general and open-ended questions. There were questions with open ends as well, so the respondents had a chance to explain their answers in more detail and the interviewer could gather valuable background information. The questions were written down in the questionnaire to ensure the following points: directness, simplicity, specification and discreteness (Barribeau et al., 2012).

Firstly, the questions were written in a direct language avoiding complex rhetoric, because the respondents of this survey were farmers who were not acquainted to complicated scientific terms. The questions were kept short and simple. That did not make the respondents feel overwhelmed by complex information. Secondly, more specific questions than general ones were asked in the survey, so necessary information would be answered and the responders could keep their answers focused to the topics. Thirdly, sensitive issues were carefully taken into consideration, e.g. income was regarded a personal topic. Therefore, the questions about income were cautiously formed, so that they were not overly personal or direct. Regarding the sequence of topics and questions inside the questionnaire, the topic of environmental quality was asked in the beginning as warm-up questions to ease the respondents into the survey (Barribeau et al., 2012). The most sensitive topic, related to economic well-being including income and percentage share of rice in the total income were not asked in the start of the survey. Furthermore, the orders of questions were designed in a way that each topic was linked to each other logically.

The first draft of the questionnaire was sent to other LEGATO project researchers for their feedbacks. After receiving the comments and considering the changes, the second draft was

made and pre-tested. Before the pre-test, the translation of the questionnaire into Vietnamese was done with the help of a local expert of LEGATO. After that, the questionnaire was examined for accuracy, legibility and completeness (Rea et al, 2005). Each question was reviewed carefully for its quality related to the use of language, layout and sequence of the questions. The English and Vietnamese versions of the questionnaire are included in the Appendix A and Appendix B.

2.5 Survey

The term "survey" generally refers to the selection of a relatively large sample of people from a pre-determined basic population, followed by the collection of a relatively small amount of data from those individuals (Kelley et al., 2003). A Survey is considered a systematic and effective instrument to collect quantitative data that will provide statistical information about the target population. In this study, due to the characteristics of the questionnaire, in-person household surveys were conducted in Sa Pa, Lao Cai and Cai Lay, Tien Giang in April and May, 2013. The implementation of the survey was carried out following the steps explained in the Rice Knowledge Bank (2009) and recommendations from *Good practice in the conduct and reporting of survey research* (Kelley et al., 2003) and *Best practices and consideration when conducting survey research* (Johnson, 2011).

Before conducting the survey, the target population group was defined. This study aimed to focus on the residents, who were from 30 to 70 years of age, had been living in the study areas for at least ten years and had been working in the rice farming sector as their main occupation at least since 2002. The respondents were supposed to be from different families and the sample size of each site was 30. All the surveys were carried out by the author.

From 13th to 16th of April, 35 in-person interviews were conducted including the pre-testing in VN_3. The interviews took place in Trung Chai, Ta Phin, Ta Van and Lao Chai communes, organized by the LEGATO project partner Institute of Policy and Management (IPAM) (Figure 10).The farmers were chosen by the contact persons of IPAM and invited to the house of a farmer, normally the place of the contact person or the commune leader.

From 23rd to 25th of May, 30 farmers in Cai Lay, Tien Giang were asked to take part in the survey (Figure 11). The interviews were implemented at six sites of VN_4 with the support of the Southern Regional Plant Protection Center (SRPPC). The farmers were also invited to the contact persons' house and gathered there.

Figure 10: Conducting interviews in Lao Cai (Pictures taken in April, 2013 by Benjamin Burkhard).

Figure 11: Conducting interviews in Tien Giang. Pictures taken in May, 2013 by Clemens Kühn (left) and Lê Thùy Dương (right).

2.6 Data Analysis

2.6.1 Data Input

After the conduct of surveys was finished, all of the data collected were translated from Vietnamese to English and put into a computer using Microsoft Excel 2010. Each question was given a code to ease the process of data analysis.

2.6.2 Statistical Data Collection

Apart from the survey, more statistical data from official sources were collected. There was an attempt to contact the National Library of Vietnam and local authorities at the research areas; however, the data were poorly available. Additionally, the websites of the Statistics Office of Tien Giang and Lao Cai did not give useful data that related to this study. In this work, the official data were taken from the General Statistics Office of Vietnam using their website (http://www.gso.gov.vn/) and the Statistical Yearbooks of Vietnam.

2.6.3 Data Analysis

In this study, Microsoft Excel 2010 was used to analyze the data which were taken from the survey and official sources. Regarding data from the survey, the data of 2002 and 2012 stand for the situation of the past and present. The data from 30 households in Lao Cai and 27 in Tien Giang were used. The mean and standard deviation (SD) of each indicator were derived from the database using the formulas and Data Analysis Tools of Excel 2010. In order to acquire the change of indicators from the past to now, data of 2002 was subtracted from data of 2012 and then the means and standard deviations were calculated.

The statistical data from official sources were also examined using the tools mentioned above. To give a better overview of the data, graphs were created to illustrate the results applying Microsoft Excel 2010.

3. Results

This chapter will give an overview of the results of the indicator analysis. The results are derived from the farmer survey data and statistical data. The trends of human well-being indicators and provisioning ecosystem service food rice indicators are presented in Subchapter 3.1 and 0. The Subchapter 3.3 will summarize the trends of all the measured indicators. The end of this chapter will describe the findings of linkages between human well-being of farmers and the provisioning ecosystem service food rice in Lao Cai and Tien Giang provinces.

3.1 Trends of Indicators of Human Well-being

In this subchapter, the results of human well-being indicators are presented along with the detailed explanation of each indicator.

3.1.1 Average Annual Income of Farmers

The average annual income of farmers was calculated from the survey data of 57 households in Lao Cai and Tien Giang provinces. Table 7 shows, how many times the present income (i.e. in 2012) was higher than the income in the past (2002), the standard deviation (SD) is also given.

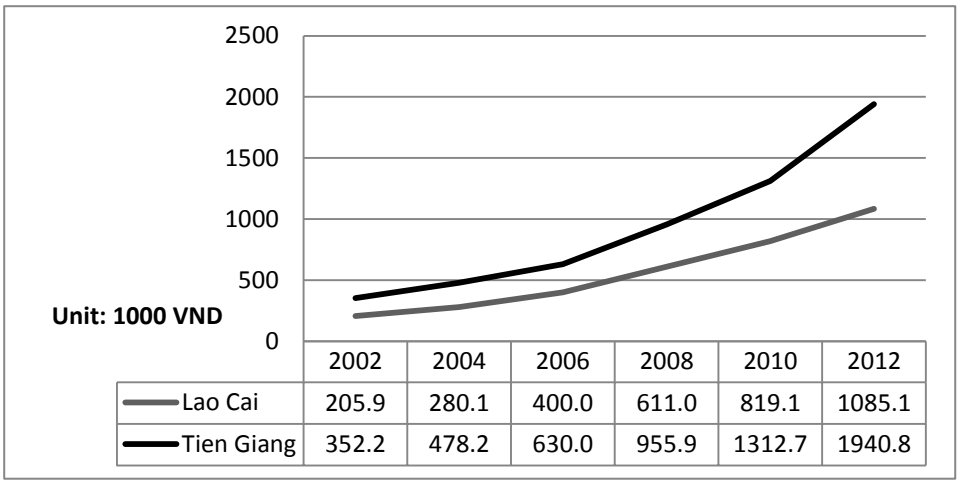
Income of the rice farmers in Lao Cai increased 2.44 times from 2002 to 2012 with a standard deviation of 0.94; while in Tien Giang, the income in 2012 was 1.98 times higher than in 2002 with a standard deviation of 0.58.

The absolute value of the income is not included in this result, since many farmers were uncomfortable with talking about their income openly. Another reason was that several farmers could not remember the exact amount of their annual earnings for the specific years, especially regarding the past. In Lao Cai, many of the farmers could not give a clear answer of how much they earned, whereas in Tien Giang, some farmers gave contradictory numbers and only wanted to give the relative changes of their income.

Table 7: Trends of average annual income of rice farmers. The increase shows the income of 2012 divided by the income of 2002 (Data source: Survey data).

Province	Increase of income	SD
Lao Cai	2.44	0.94
Tien Giang	1.98	0.58

Relevant statistical data regarding income of rice farmers could not be found. Only data of monthly income per capita in the two provinces were available from GSO for the years 2002 to 2012. As it is shown in Figure 12, the general trend in monthly income per capita was also increasing in both provinces. The monthly income per capita of Lao Cai and Tien Giang had a similar rise of more than five times in ten years (i.e. 5.3 times and 5.5 times respectively). In the table in Figure 12, it can be seen that Lao Cai had lower income per capita and slower development of per capita income than Tien Giang. Comparing the statistical data with the result of the survey, it had been noted that the increase in the income of the rice farmers was at a slower pace than the income per capita rise in both places. Despite the fact that income per capita in Lao Cai was less than in Tien Giang, the income of the farmers in Lao Cai increased faster than in Tien Giang.



	2002	2004	2006	2008	2010	2012
Lao Cai	205.9	280.1	400.0	611.0	819.1	1085.1
Tien Giang	352.2	478.2	630.0	955.9	1312.7	1940.8

Figure 12: Monthly income per capita in Lao Cai and Tien Giang (Data source: GSO, 2014).

3.1.2 Savings Rate of Average Annual Income

Taken from the survey, the data in Table 8 illustrate an increase in the rate of savings from average annual income. According to the survey data, the savings rates in Lao Cai and Tien Giang increased 3 percentage points and 9 percentage points respectively in ten years. Farmers in Tien Giang could save more of their income than those in Lao Cai. However, the survey data of Lao Cai revealed that 29 out of 30 persons did not have any savings and only one participant indicated 60 % savings of the income in the past. In 2012, 16 persons in Lao Cai answered that they could not save anything. In Tien Giang, 17 of 27 respondents said, they did not save anything from their average annual income in 2002. For the present time eight persons in Tien Giang responded 0 % savings rate with regards to their average annual income.

Table 8: Results of *savings rate of average annual income* (Data source: Survey data).

Province	Savings change	SD	Savings past	SD	Savings present	SD
Lao Cai	3 pp	9 pp	2 %	11 pp	5 %	10 pp
Tien Giang	9 pp	12 pp	8 %	13 pp	17 %	16 pp

3.1.3 Share of Average Annual Income from Rice

Table 9 shows the results for the indicator *share of average annual income from rice*. In Tien Giang, there was a three percentage point (pp) decline from 57 % in 2002 to 54 % in 2012 with the standard deviation of 18 percentage points in the share of the annual income that came from rice. In Lao Cai, the interviewed farmers stated that rice contributed to none of their annual income due to the fact that they only had one harvest each year which only produced tightly enough rice for the self-consumption of the families. As a result, the farmers did not have any spare rice for sale. Apart from rice, additional sources of income of the interviewed farmers can be found in Table 10. In Lao Cai, most of the farmers made a living from animal farming, being hired workers or growing vegetables. In Tien Giang, the farmers had side jobs such as hired workers, growing fruits, animal farming and making handicraft.

Table 9: Trends of *share of average annual income from rice* (Data source: Survey data).

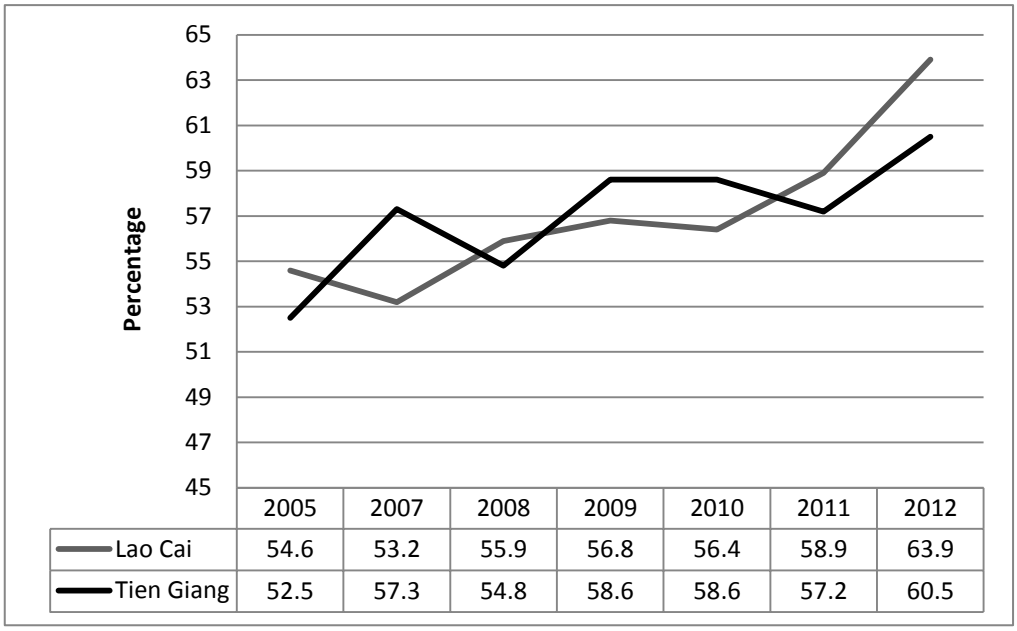
Province	Income from rice change	SD	Income from rice past	SD	Income from rice present	SD
Lao Cai	0 pp	0 pp	0 %	0 pp	0 %	0 pp
Tien Giang	-3 pp	18 pp	57 %	22 pp	54 %	24 pp

Table 10: Additional sources of income of rice farmers in Lao Cai and Tien Giang. One farmer could have more than one source of income (Data source: Survey data).

Lao Cai		Tien Giang	
Source of income	Number of farmers	Source of income	Number of farmers
Animal farming	21	Hired work	9
Hired work	11	Fruit	9
Vegetables	11	Animal farming	5
Thao Qua	9	Handicraft	5
Embroidery	7		
Other agricultural products	4		
Tourism	2		

3.1.4 Employment rate

The data on *employment rate* were collected from GSO (2014); however data of the years 2002, 2003, 2004 and 2006 were not available on the database. Figure 13 demonstrates the changes of *employment rate* of people from 15 years of age and above in comparison to the whole population in Lao Cai and Tien Giang. The general trend the *employment rates* from 2005 to 2012 was increasing; however there were some fluctuations in between the years. The two provinces had a similar percentage of employment (i.e. 63.9% in Lao Cai and 60.5% in Tien Giang in 2012).



	2005	2007	2008	2009	2010	2011	2012
Lao Cai	54.6	53.2	55.9	56.8	56.4	58.9	63.9
Tien Giang	52.5	57.3	54.8	58.6	58.6	57.2	60.5

Figure 13: Rate of employment of people from 15 years of age and above in relation to the whole population (Data source: GSO, 2014).

3.1.5 Share of Employees Working in Rice Production

Relevant data for the indicator *share of employees working in rice production* were planned to be collected from official sources. Unfortunately, there were no statistical data available for the calculation of this indicator.

The available statistical data were the share of employees working in the agricultural sector on the regional scale. That data did not point out specifically the percentage of employees working in rice production and was only valid for large regions of Vietnam covering several provinces. Additionally, data concerning the share of employees working in agriculture, fishery and forestry sectors by province could be found. The data combined the three sectors in one number and could therefore not be used for this study. Hence, the indicator *share of employees working in rice production* could not be used in the data analysis.

3.1.6 Population Structure According to Age Groups

Statistical data for the indicator *population structure according to age groups* were only available in country and regional scales. Nevertheless the statistical data of trends in *rural* and *urban population* in Tien Giang and Lao Cai were available, which are demonstrated in Figure 14.

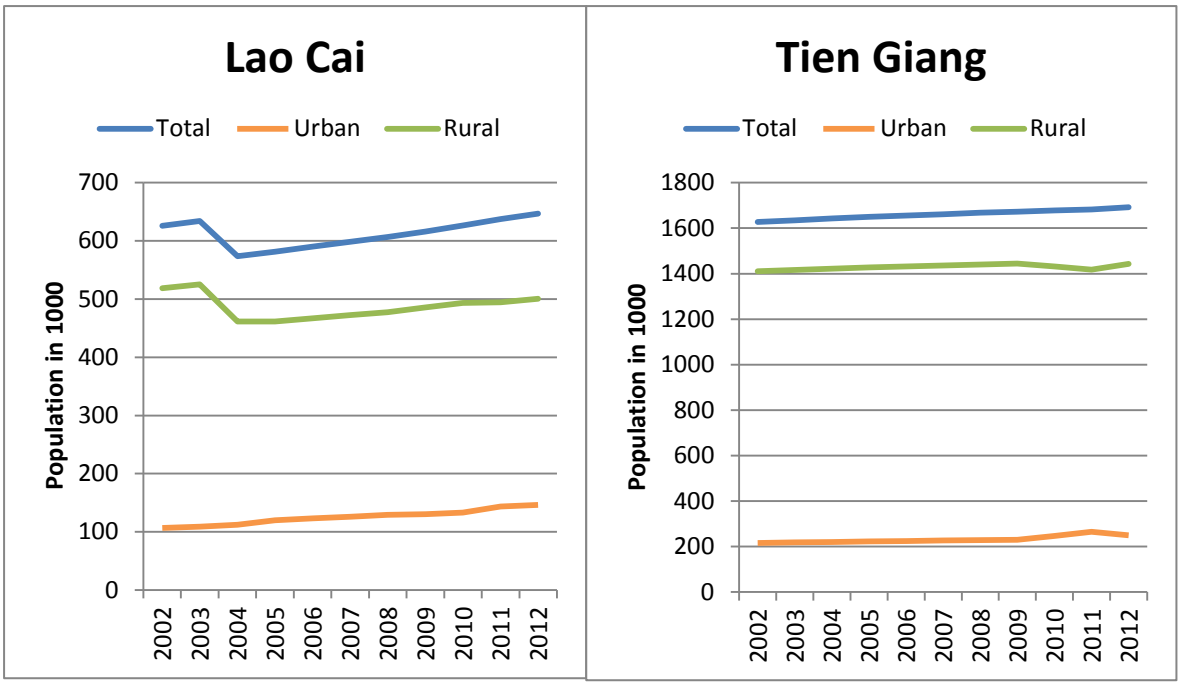


Figure 14: Trends of total rural and urban population in Lao Cai and Tien Giang (Data source: GSO, 2014).

In general, the total population of Lao Cai increased rapidly in the last ten years. In Lao Cai, the *rural population* increased almost at the same speed with the urban one. The Than Uyen district was separated from Lao Cai to join the Lai Chau province in 2004. That is the reason for a decrease of 60300 people in the total and *rural population* of Lao Cai in 2004.

Tien Giang had a steady gain of its total population. In 2009, administrative boundaries of Chau Thanh and Cho Gao districts were changed in order to expand My Tho city; therefore the *rural population* of Tien Giang declined in 2009.

In both provinces, the *rural population* was much higher than *the urban population*. The *rural population* of Tien Giang was approximately seven times higher than the *urban population*, whereas in Lao Cai the *rural population* in 2012 was 3.4 times the size of the *urban population*.

3.1.7 Ratio of Women/Men Working in Rice Production

Detailed statistical data regarding the *ratio of women/men working in rice production* were not available for the calculation of such indicator.

3.1.8 Net Migration per 1000 Inhabitants

Figure 15 illustrates the trends in migration of Lao Cai from 2005 to 2012. From 2005 to 2010, the out-migration was much higher than the in-migration, which resulted in a fluctuation of the net migration between -1.2 and -0.1 persons per 1000 inhabitants; an exceptionally low net migration (-4.9) was recorded in 2007. Only in the year 2011, the net migration value was positive, with 1 person per 1000 inhabitants. In general, the net migration differed much in Lao Cai, from -4.9 to 1.

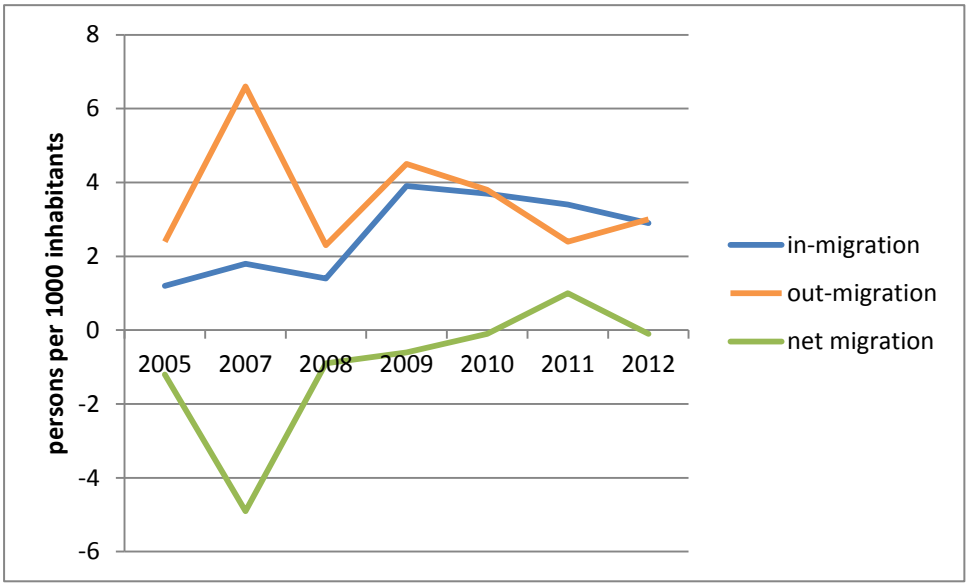


Figure 15: Migration rates in Lao Cai from 2005 to 2012 (Data source: GSO, 2014).

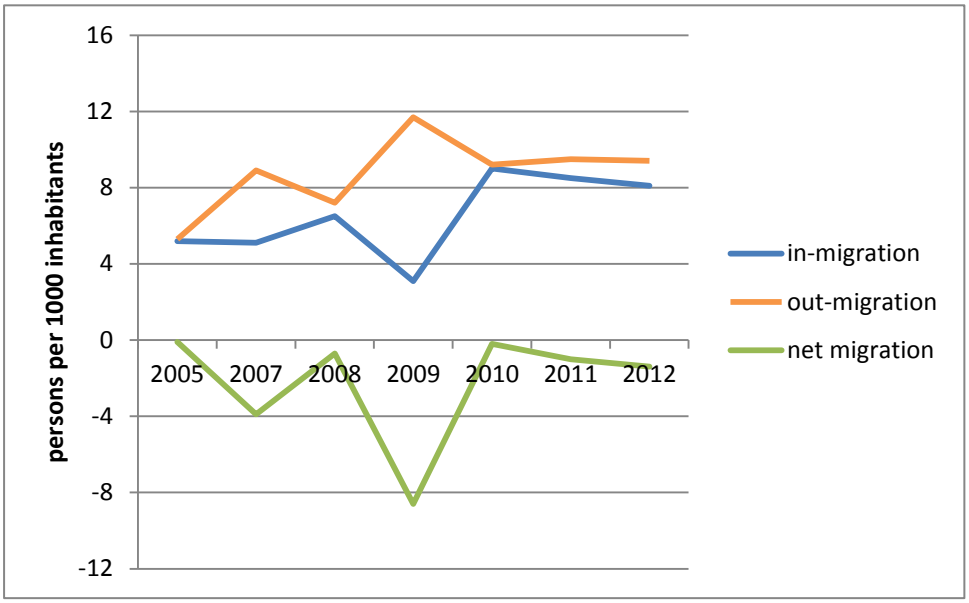


Figure 16: Migration rates in Tien Giang from 2005 to 2012 (Data source: GSO, 2014).

In Tien Giang, the net migration value was always negative from 2005 to 2012, and fluctuated between -8.6 and -0.1 persons per 1000 inhabitants. In the year 2009, the in-migration hit the lowest point (3.1 persons per 1000 inhabitants) and the out-migration reached a peak at 11.7 persons per 1000 inhabitants. Therefore, 2009 was the year with the lowest value of net migration. In Tien Giang, there were higher in- and out-migration rates than in Lao Cai.

However, the data that were found only illustrated the migration situation of seven years, from 2005 to 2012, and the year 2006 was missing in the GSO (2014) dataset.

3.1.9 Education

The three indicators that were put under the category of education could not be realized in the study regions. In the testing phase of the survey, many farmers found it inconvenient or tried to avoid talking about their education level. As a result, the questions about education were not included in the survey after the testing phase. Moreover, there were no statistical data about the education level of farmers available from official sources.

Therefore, the three following indicators were considered impracticable under the conditions of the two research regions:

- *Percentage of farmers finished secondary school;*
- *Percentage of farmers finished high school;*
- *Percentage of farmers' children visiting high school.*

3.1.10 Share of Locally Produced Rice Supply in the Region

The original idea behind the indicator *share of locally produced rice supply in the region* was to see how much rice from the production of the regions was used to sustain the local food security. Local authorities were asked if they could provide such information, however they did not have any records on this topic.

To make another attempt to indicate the nutrition category of human well-being, the alternative indicator *self-supply of rice* was created. The indicator *self-supply of rice* measured, how many months in one year the rice farmers had enough rice from their farms to meet the internal consumption of their families.

Table 11: Self-supply of rice in Lao Cai and Tien Giang in months per year (Data source: Survey data).

Province	Self-supply rice change	SD	Self-supply rice past	SD	Self-supply rice present	SD
Lao Cai	2.5	3.3	8.1	2.4	10.6	2.4
Tien Giang	0	0	12	0	12	0

Farmers in Tien Giang produced enough rice to supply their families during the whole year in the past and present as shown in Table 11. In Lao Cai, the situation was different, since the farmers only grow one season of rice each year. In the past, farmers in Lao Cai only had enough rice from their farms for 8.1 months of the year and in the present, the average months of *self-supply of rice* were 10.6, with a change of 2.5 months. There were three families whose results of changes were negative (i.e. -3, -4 and -7), as they had less rice in the present than in the past due to the expansion of the family.

3.1.11 Number of Doctors per 1000 Inhabitants

Considering the *number of doctors per 1000 inhabitants*, the general trend in both provinces was an increase, which indicated an improvement of the health infrastructure in Lao Cai and Tien Giang. The *number of doctors per 1000 inhabitants* in Lao Cai was higher than in Tien Giang during the whole examination period (Figure 17). In Lao Cai, there was a rapid growth of the *numbers of doctors per 1000 inhabitants* from 2002 to 2012. During the ten years, the number of doctors rose 1.7 times from 0.46 in 2002 to 0.77 doctors per 1000 inhabitants in

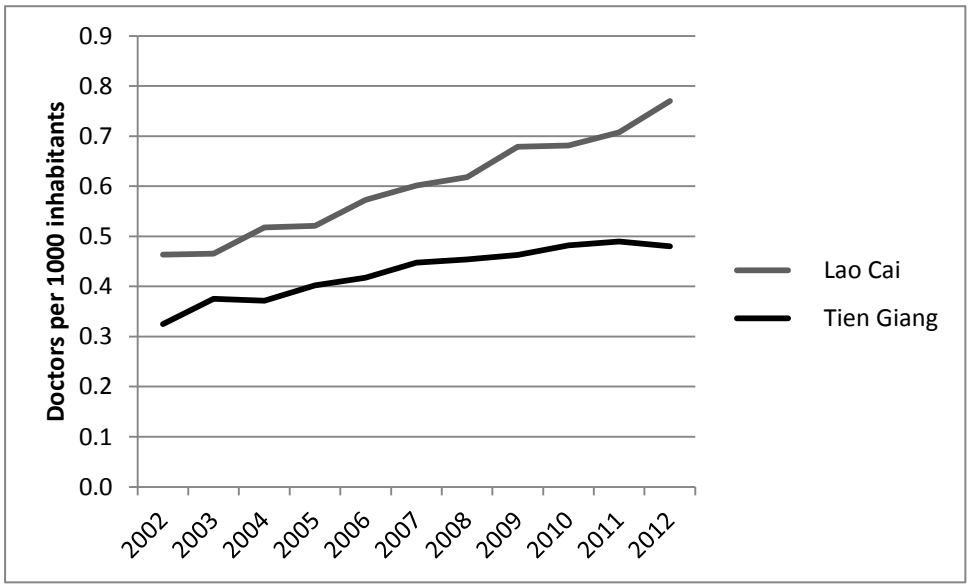


Figure 17: *Number of doctors per 1000 inhabitants* in Lao Cai and Tien Giang (Data source: GSO, 2014).

2012. The *number of doctors per 1000 inhabitants* increased rather moderately by 1.5 times in Tien Giang during the ten years of the study period.

3.1.12 Hospital Beds per 1000 Inhabitants

From the statistical source of GSO (2014), the data for *hospital beds per 1000 inhabitants* were various, including beds in different categories of healthcare institutes that provide beds to patients. In this indicator, the number of beds was counted from the government sector of healthcare facilities including hospitals, regional polyclinics, sanatoriums, rehabilitation hospitals and medical service units. Including all the different kinds of governmental hospitals enabled a holistic approach to assess the availability of health infrastructure in the study regions.

From 2002 to 2012, the development of the *number of hospital beds per 1000 inhabitants* was parallel in Lao Cai and Tien Giang with a slowly increasing trend. In Tien Giang, the *number of hospital beds per 1000 inhabitants* was much lower than it was in Lao Cai during the whole examination period. In 2002, the number of hospital beds in Tien Giang was 1.6 beds per 100 inhabitants and extended to 1.9 beds per 1000 persons during the following ten years.

The peak in the *number of hospital beds per 1000 inhabitants* in Lao Cai in the year 2004 can be explained by the population decrease, which was caused by an administrative reform. There were some fluctuations of the indicator in Lao Cai from 2006 to 2009. However, the *number of hospital beds per 1000 inhabitants* in Lao Cai increased by 0.4 in ten years, from 3.6 beds in 2002 to 4.0 beds in 2012.

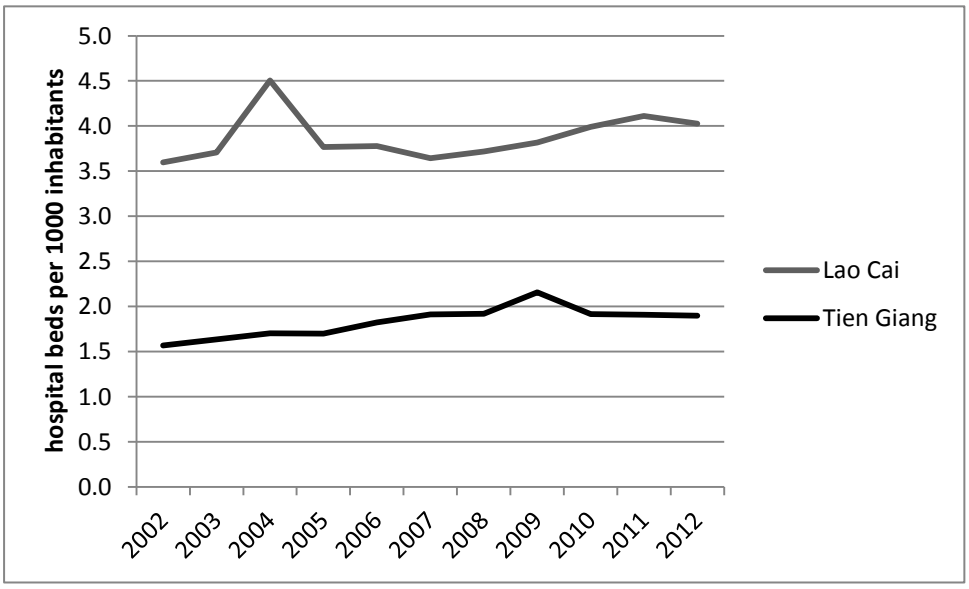


Figure 18: Hospital beds per 1000 inhabitants in Lao Cai and Tien Giang (Data source: GSO, 2014).

3.1.13 Personal Satisfaction and Happiness

This indicator was aimed to assess rice farmers' *personal satisfaction and happiness*. Farmers were asked to evaluate in the scale from 1 to 10 how happy and satisfied they were with their lives (1 = not satisfied at all, 10 = perfectly satisfied). This was the survey question which respondents were most willing to answer.

From Table 12, it can be seen that the trends in the *personal satisfaction and happiness* of rice farmers were relatively similar in the two study provinces. The *personal satisfaction and happiness* of farmers in Lao Cai and Tien Giang increased 1.4 and 1.5 points in ten years. Tien Giang rice farmers have been more satisfied with their lives than rice farmers in Lao Cai with a score of 7.3 for the present and 5.8 for the past. Lao Cai farmers graded their personal happiness two points less than Tien Giang farmers (5.3 for the present and 4 for the past).

With this indicator, it was possible to ask the farmers for the anticipation of their personal happiness in the future. Farmers in both provinces expected an increase of happiness in the future. Astonishingly the future happiness were graded exactly the same in Lao Cai and Tien Giang (8.8). As the farmers of both research regions supposed the same degree of happiness in the future, it was obvious that the expected increase in happiness and satisfaction of rice farmers in Lao Cai was higher than in Tien Giang (increase from 5.3 to 8.8).

Table 12: *Personal satisfaction and happiness* of rice farmers in Lao Cai and Tien Giang on a scale from 1 (not happy at all) to 10 (completely happy), (Data source: Survey data).

Province	Happiness change	SD	Happiness past	SD	Happiness present	SD	Happiness future	SD
Lao Cai	1.4	1.8	4.0	1.6	5.3	1.9	8.8	0.9
Tien Giang	1.5	1.9	5.8	1.6	7.3	1.5	8.8	1.5

3.1.14 Average Working Time During Busy Period

The indicator *average working time during busy period* shows how many hours per day the rice farmers spend for rice cultivation during the busy time of the season (including soiling, seeding, harvesting and processing of the harvest). It can be seen in Table 13 that the working time of rice farmers was constant in Lao Cai and Tien Giang. There was no change in the amount of time that farmers have been spending to work in rice production in the ten years study period. However, in Tien Giang, an average rice farmer spent 0.9 hour less working on the field (7.8 hours/day) than an average rice farmer in Lao Cai (8.6 hours/day).

Table 13: Average working hours per day of rice farmers for rice cultivation during the busy period (Data source: Survey data).

Province	Working time busy period change	SD	Working time busy period past	SD	Working time busy period present	SD
Lao Cai	0.00	0.26	8.6	1.2	8.6	1.2
Tien Giang	0.00	0.00	7.8	1.6	7.8	1.6

3.1.15 Average Working Time During Other Periods

The term "other periods" here can be understood as the rest of a season of rice growth, apart from the busy time, when farmers do not have to work much on the rice fields. During this time, they work mainly to ensure the normal growth of rice, to avoid pests and weeds and to take care of proper irrigation.

Table 14 shows the result of changes in average working hours of farmers during other periods of rice cultivation in the last ten years. In general, the farmers did not have to spend much time working on the field during this time of the season, only 1.3 hours on average in Lao Cai and 1.2 hours on average in Tien Giang with a standard deviation of 0.5 hours in both places. However, in Lao Cai, from 2002 to 2012, there was a slight change, which indicated that the farmers spent 0.03 hours per day less in the field during the other periods.

Table 14: Average working hours per day of rice farmers for rice cultivation during other periods (Data source: Survey data).

Province	Working time other periods change	SD	Working time other periods past	SD	Working time other periods present	SD
Lao Cai	-0.03	0.18	1.3	0.5	1.3	0.5
Tien Giang	0.00	0.00	1.2	0.5	1.2	0.5

3.1.16 Time Spent for Leisure and Personal Care

The aim of this indicator was to figure out how many hours per day each respondent had for leisure and personal care, the average non-working time of the day. Leisure and personal care could be understood as activities that farmers do in their free time, when they do not have to work, such as reading newspapers, watching TV, visiting or gathering with neighbors.

Table 15 depicts the result of the survey concerning the indicator *time spent for leisure and personal care*. It is obvious that the free time of farmers in both provinces had a similar increase of 1.2 hours per day in Lao Cai and 1.1 hours per day in Tien Giang. However, farmers from Tien Giang had more free time than those from Lao Cai, in the past and in the present.

Regarding Lao Cai, in 2002, 17 out of 30 respondents stated that they did not have any free time at all. In 2012, the number of respondents in Lao Cai who had no free time was four. In Tien Giang, there were only three respondents who did not have free time in the past, whereas all survey participants had time for leisure and personal care in the present.

Table 15: Hours per day that rice farmers spent for leisure and personal care activities (Data source: Survey Data).

Province	Leisure and personal care time change	SD	Leisure and personal care time past	SD	Leisure and personal care time present	SD
Lao Cai	1.2	1.9	1.3	1.9	2.5	2.3
Tien Giang	1.1	1.9	2.6	1.3	3.6	1.5

3.1.17 Satisfaction with the Quality of Air

Table 16 contains the results of *satisfaction with the quality of air* of rice farmers in Lao Cai and Tien Giang in the years 2002 and 2012. The farmers were asked to evaluate their satisfaction of air quality from using three different categories: *not satisfied* (1), *satisfied* (2) and *very satisfied* (3). The higher the number, the more satisfied the farmers were with the air quality.

The results in Table 16 indicate that the trends in air quality satisfaction in Lao Cai and Tien Giang were different. In Lao Cai, the satisfaction of farmers with the air quality declined (-0.3) from 2002 to 2012. While in Tien Giang, the air quality was considered as being better with a small increase (0.1) of satisfaction. In general, respondents in the two research regions were pleased with the air quality, as it was graded between *satisfied* and *very satisfied*.

Table 16: *Satisfaction with the quality of air* in Lao Cai and Tien Giang (Data source: Survey data).

Province	Air quality satisfaction change	SD	Air quality satisfaction past	SD	Air quality satisfaction present	SD
Lao Cai	-0.3	0.9	2.3	0.7	2.0	0.8
Tien Giang	0.1	0.3	2.2	0.5	2.3	0.5

In addition, the respondents were asked to describe more about the air quality in their residential areas. Four farmers in Lao Cai and three farmers in Tien Giang gave reasons for the degradation of air quality which can be seen in Table 17

.

Table 17: Sources of air pollution mentioned by interviewed farmers (Data source: Survey data).

Lao Cai		Tien Giang	
Source of pollution	Number of farmers	Source of pollution	Number of farmers
Deforestation	1	Deforestation	1
Private emissions	2	Animal farming	1
Traffic	1	Traffic	1

3.1.18 Satisfaction with the Quality of Water

The indicator *satisfaction with the quality of water* was split up into two different indicators: *satisfaction with the quality of natural water* and *satisfaction with the quality of household water*. During the assessment the scale was used for the indicator *satisfaction with the quality of water* as for the indicator s*atisfaction with the quality of air* (Section 3.1.17).

The results in Table 18 show a decline in the satisfaction with natural water quality of the farmers in both provinces. It decreased from 2.1 in 2002 to 1.3 in 2012 in Lao Cai and from 2.0 in 2002 to 1.0 in 2012 in Tien Giang, which means that most of the farmers were not pleased with the quality of natural water in the present.

Table 18: Satisfaction of rice farmers with the quality of natural waters (Data source: Survey data).

Province	Natural water quality change	SD	Natural water quality past	SD	Natural water quality present	SD
Lao Cai	-0.8	0.7	2.1	0.6	1.3	0.5
Tien Giang	-0.9	0.4	2.0	0.3	1.0	0.2

The sources of pollution of natural waters pointed out by rice farmers in Lao Cai and Tien Giang differed, they are shown in Table 19. Accordingly, garbage and private waste water were mentioned in both places as two of the main reasons which caused pollution of natural waters. The other sources in Lao Cai were deforestation (mentioned three times) and fertilizer use (mentioned one time) and those in Tien Giang were animal farming (mentioned six times), pesticides (mentioned four times), dykes prevent water exchange (mentioned three times) and various sources (mentioned four times).

Table 19: Sources of water pollution mentioned by interviewed farmers, several sources per farmer were possible (Data source: Survey data).

Lao Cai		Tien Giang	
Source of pollution	Number of farmers	Source of pollution	Number of farmers
Garbage	5	Private waste water	6
Private waste water	5	Animal farming	6
Deforestation	3	Pesticides	4
Pesticides	1	various sources	4
		Dykes prevent water exchange	3
		Garbage	2

It can be seen in Table 20 that farmers in Lao Cai and Tien Giang were slightly more satisfied with the quality of household water in the present than ten years before. The term household water used in this study is defined as the water which is used to serve the purpose of hygiene, drinking and eating of the family. In Lao Cai, farmers were more satisfied with quality of the household water which was used in their families (2.3 in 2002 and 2.4 in 2010) than farmers in Tien Giang (1.9 in 2002 and 2.1 in 2010). In principle, the results in Table 18 and Table 20 indicated that the respondents were more satisfied with their household water quality than with the quality of natural waters.

Table 20: Satisfaction of rice farmers with the quality of household water (Data source: Survey data).

Province	**Household water quality change**	**SD**	**Household water quality past**	**SD**	**Household water quality present**	**SD**
Lao Cai	0.1	0.6	2.3	0.6	2.4	0.6
Tien Giang	0.2	0.4	1.9	0.4	2.1	0.5

3.2 Trends of Indicators of the Provisioning Ecosystem Service Food Rice

3.2.1 Yield of Paddy per Season

Due to the different conditions in the two study regions, the method for calculating the indicator y*ield of paddy per season* in Lao Cai was different from the method used in Tien Giang. In Lao Cai, there is only one season of paddy per year and the *yield of paddy* was calculated by the total amount of harvested paddy divided by the total amount of seeds used. This method was applied, because the farmers in Lao Cai could not indicate the area of their terraces. The results of this indicator are illustrated in Table 21. From one kilogram of seeds the farmers of Lao Cai could harvest 59.5 kg of paddy in 2002. The amount of paddy received from one kilogram of seeds doubled in ten years, with 121 kg of paddy harvested from each kilogram of seeds in 2012.

Table 21: Trends of the *yield of paddy* in Lao Cai in kg of paddy per kg of seeds (Data source: Survey data).

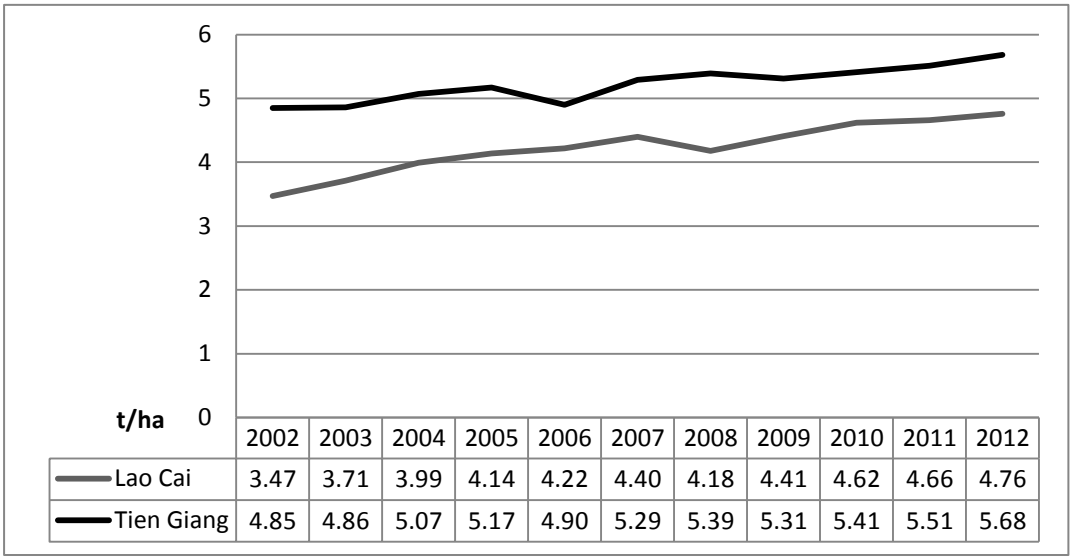
Yield of paddy change	SD	Yield of paddy past	SD	Yield of paddy present	SD
61.5	35.8	59.5	26.9	121	21

As shown in Table 22, the *yield of paddy per season* in Tien Giang remained constant at 4.4 tons per hectare during the ten examined years. There are three seasons of paddy in Tien Giang and the numbers shown in Table 22 are the average yield per season taken from the answers of farmers.

Table 22: Trends of the *yield of paddy per season* in Tien Giang in tons/ha (Data source: Survey data).

Yield of paddy change	SD	Yield of paddy past	SD	Yield of paddy present	SD
0.0	0.7	4.4	0.8	4.4	0.9

Figure 19 represents the statistical data trends of paddy yield in Lao Cai and Tien Giang from 2002 to 2012. The data in Figure 19 were obtained from the GSO (2014) database. There were declines in Lao Cai and Tien Giang in 2006 and 2008 but the general trend of paddy yield was rising during the ten years. The statistical data for Tien Giang is in contrast to the survey result, where the yield of paddy was stable. In the survey, the trend of yield increase of Lao Cai was higher than in the statistical data.



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Lao Cai	3.47	3.71	3.99	4.14	4.22	4.40	4.18	4.41	4.62	4.66	4.76
Tien Giang	4.85	4.86	5.07	5.17	4.90	5.29	5.39	5.31	5.41	5.51	5.68

Figure 19: Average *yield of paddy per season* in Lao Cai and Tien Giang (Data source: GSO, 2014).

There was another data source from Anika Marxen, a LEGATO project scientist, who was kindly sharing the preliminary rice yield data. According to the data of Marxen, the mean rice yield of three seasons in 2012 in Tien Giang was 6.1 tons per hectare. The number was determined for the rice grains with hulls and measured after oven-drying the samples. In Lao Cai, the rice yield in 2012 was 2.8 tons per hectare. The methods of sampling in the two regions were different, as in Tien Giang area sampling was conducted, whereas in Lao Cai hill sampling was used. However, it can be seen that the yield in Tien Giang was much higher than in Lao Cai. Regrettably, no trend could be derived from the data of Marxen, as the yield was only measured for one year.

3.2.2 Number of Harvests

The *number of harvests* in both research regions remained the same from 2002 to 2012. According to the survey data and statistical data, there were three harvests per year in Tien Giang and one harvest per year in Lao Cai.

3.2.3 Fertilizer Use

Quantification of the *fertilizer use* per ton of rice output in the research areas was found to be more complex than expected. Firstly, the variety of fertilizers which were used in Lao Cai and Tien Giang was high and each farmer had different practice of combining them on the rice fields. Therefore, it was more reasonable to calculate the fertilizer inputs per hectare in Tien Giang regarding each sort of fertilizer separately. Since the farmers in Lao Cai did not specify

the area of their rice terraces, only the total amount of fertilizers which was used on the fields in one season could be computed. This was done by adding up the fertilizer uses of all the 30 interviewed families.

Table 23 indicates the uses of sorts of fertilizers by 30 interviewed families in Lao Cai in the past and in the present. Generally, only the amount of organic fertilizer was reduced while the inorganic fertilizer inputs significantly increased. 12 out of 30 farmers in Lao Cai reported that they did not use organic fertilizer for their fields since 2002. Only one farmer in Lao Cai mentioned the use of Potassium in their field.

Table 23: Total use of fertilizers by 30 families in kg in one season in Lao Cai (Data source: Survey data).

Use / Fertilizer	Change	Past	Present
Organic	-43530.0	53430.0	9900.0
N-Nitrogen	1593.0	470.0	2063.0
P-Phosphorus	1940.0	775.0	2715.0
K- Potassium	200.0	0.0	200.0
NPK	3270.0	350.0	3620.0

In Tien Giang, the farmers have not been using organic fertilizer for their fields since long. The farmers stated that they only applied inorganic fertilizers on their paddy fields, which were nitrogen, phosphorus, potassium, NPK and diammonium phosphate. The uses of all sorts of inorganic fertilizers, except phosphorus, were increasing in Tien Giang from 2002 to 2012.

Table 24: Average fertilizer use in kg per hectare per season in Tien Giang (Data source: Survey data).

Use / Fertilizer	Change	SD	Past	SD	Present	SD
Organic	-	-	-	-	-	-
N-Nitrogen	95.7	271.6	596.2	409.3	691.9	497.6
P-Phosphorus	-18.5	96.2	38.9	211.8	37.0	133.4
K- Potassium	5.8	113.9	228.1	253.1	234.0	228.6
NPK	189.4	271.6	704.4	606.4	893.8	852.0
DAP- Diammonium Phosphate	78.8	235.9	534.4	391.5	613.2	463.0

3.2.4 Machinery Use and Labor Input

There was not enough information to quantify the amount of time of *machinery use* and *labor input* per ton of rice output of farmers in Lao Cai and Tien Giang. The alternative choice was to indicate *machinery use* in percentage of the stages of rice cultivation including soiling, harvesting, threshing and husking. The results are shown in Table 25. In Tien Giang, soiling, threshing and husking were done completely with the assistance of machinery during the ten years of the examination period. Apart from harvesting and threshing which were done completely by human input, the percentage of machinery use in soiling and husking increased in Lao Cai.

Table 25: *Machinery use* in percentage of work for soiling, harvesting, threshing and husking of rice (Data source: survey data).

		Lao Cai		Tien Giang	
		Machinery use	SD in pp	Machinery use	SD in pp
Soiling	change	45 pp	48	0 pp	0
	past	0 %	0	100 %	0
	present	45 %	48	100 %	0
Harvesting	change	0 pp	0	11 pp	32
	past	0 %	0	0 %	0
	present	0 %	0	11 %	32
Threshing	change	0 pp	0	0 pp	0
	past	0 %	0	100 %	0
	present	0 %	0	100 %	0
Husking	change	10 pp	31	0 pp	0
	past	90 %	31	100 %	0
	present	100 %	0	100 %	0

3.2.5 Export and Import of Rice from the Region

Unfortunately, there was no available data related to the indicators e*xport of rice from the region* and *import of rice to the region.* Therefore, the two indicators could not be assessed in the study provinces.

3.3 Summary of Identified Trends of Indicators

Table 26 and Table 27 sum up the trends of indicators which were found in the survey data and the statistical data of official sources. The two tables only include the indicators which were applicable in the two research regions. Table 26 shows the trends of indicators of the provisioning ecosystem service food rice and Table 27 displays the trends of indicators of human well-being in Lao Cai and Tien Giang.

Table 26: Main trends of the provisioning ecosystem service food rice indicators in Lao Cai and Tien Giang.

Indicator	Lao Cai	Tien Giang
Yield of paddy	↗	↗
Number of harvests	→	→
Use of organic fertilizer	↘	-
Use of nitrogen (N) fertilizer	↗	↗
Use of phosphorus (P) fertilizer	↗	↘
Use of potash (K) fertilizer	↗	↗
Use of NPK fertilizer	↗	↗
Use of Diammonium Phosphate (DAP) fertilizer	-	↗
Machinery use for soiling	↗	→
Machinery use for harvesting	→	↗
Machinery use for threshing	→	→
Machinery use for husking	↗	→

Table 27: Main trends of the human well-being indicators in Lao Cai and Tien Giang.

Category	Indicator	Lao Cai	Tien Giang
Income	Average annual income of farmers	↗	↗
	Savings rate of average annual income	↗	↗
	Share of average annual income from rice	→	↘
Employment	Employment rate	↗	↗
Demography	Rural population	↘	→
	Urban population	↗	↗
	Net migration per 1000 inhabitants	→	→
Nutrition	Self-supply of rice	↗	→
Health infrastructure	Number of doctors per 1000 inhabitants	↗	↗
	Hospital beds per 1000 inhabitants	↗	↗
Personal well-being	Personal satisfaction and happiness	↗	↗
Work and life balance	Average working time during busy period	→	→
	Average working time during other periods	→	→
	Time spent for leisure and personal care	↗	↗
Environmental quality	Satisfaction with the quality of air	↘	→
	Satisfaction with the quality of natural waters	↘	↘
	Satisfaction with the quality of household water	→	→

3.4 Adaptation of the Indicator Set

Throughout the application of the proposed indicator set, some indicators could not be measured due to a lack of statistical data or conditions found in the research regions that made their application impractical. Some indicators could be replaced with other substitute indicators, while some were irreplaceable. This subchapter provides a summary of the adaptation of the indicator set.

3.4.1 Indicators of the Provisioning Ecosystem Service Food Rice

From the proposed indicator set which was introduced in Table 6 (Section 2.3.1), the two indicators *yield of paddy* and *number of harvests* proved to be and applicable in the study areas. Unfortunately, the indicators *machinery use,* and *labor input* could not be calculated within the scale of this study due to their complexity. To be able to measure the *machinery use* and *labor input* per ton of rice output, further investigation is required. The indicator *fertilizer use* was separated into six different indicators: *use of organic fertilizer, use of nitrogen (N) fertilizer, use of phosphorus (P) fertilizer, use of potash (K) fertilizer*, *use of NPK fertilizer and use of diammonium phosphate (DAP) fertilizer.* Limitations of available statistical data obstructed the measure of the *export of rice from the region* and *import of rice to the region* indicators. The indicator of *machinery use* was divided into the four indicators *machinery use for soiling*, *machinery use for harvesting*, *machinery use for threshing* and *machinery use for husking.* Table 28 demonstrates the adapted indicators for the provisioning ecosystem service food rice.

Table 28: Adapted indicator set for the provisioning ecosystem service food rice in Lao Cai and Tien Giang.

Indicator	Parameter Unit	Data Sources
Yield of paddy	tons/ha/season	Farmer survey, statistical data
Number of harvests	1 to 3 per year	Farmer survey
Use of organic fertilizer	kg/ha/season[3] kg/season[4]	Farmer survey
Use of nitrogen (N) fertilizer	kg/ha/season[3] kg/season[4]	Farmer survey
Use of phosphorus (P) fertilizer	kg/ha/season[3] kg/season4	Farmer survey
Use of potash (K) fertilizer	kg/ha/season[3] kg/season[4]	Farmer survey
Use of NPK fertilizer	kg/ha/season[3] kg/season[4]	Farmer survey
Use of diammonium phosphate (DAP) fertilizer	kg/ha/season	Farmer survey
Machinery use for soiling	%	Farmer survey
Machinery use for harvesting	%	Farmer survey
Machinery use for threshing	%	Farmer survey
Machinery use for husking	%	Farmer survey

3.4.2 Indicators of Human Well-being

Regarding human well-being indicators, most of the proposed indicators were proven to be practical in the research provinces. The indicators in the income category were applicable, even though the absolute number of *average annual income* of the farmers could not be calculated. The availability of statistical data was a hindrance to calculate the indicators *share of employees working in rice production, population structure according to age groups*, *ratio of women/men working in rice production, farmers finished secondary school*, *farmers finished high school*, *farmers' children visiting high school* , *locally produced rice supply in the region.*

[3] Applied in Tien Giang
[4] Applied in Lao Cai

However, the demography development could still be captured by the substitute indicators *rural population* and *urban population. Locally produced rice supply in the region* was replaced by the indicator *self-supply of rice* which was measuring the months per year that the farmers could supply their families with rice from their own fields.

Regarding the environmental quality, the survey data enabled a more specific indication of the satisfaction with water quality with the help of the two indicators *satisfaction with the quality of natural waters* and *satisfaction with the quality of household water*. The complete adapted set of human well-being indicators is displayed in Table 29.

Table 29: Adapted indicator set for human well-being as it was applied in the study regions of Lao Cai and Tien Giang.

No	Dimension	Category	Definition (adapted from Busch et al. 2011 and OECD 2011)	Indicator	Parameter Unit	Data Sources
1	Economic well-being	Income	Disposable income; that is, the income available to individuals for meeting their respective needs. The material basis available to each individual for participating in social life.	Average annual income of farmers	VND	Farmer survey, statistical data
2				Savings rate of average annual income	%	
3				Share of average annual income from rice	%	
4		Employment	Diversity and security of available jobs within the region.	Employment rate	%	Statistical data
5	Social well-being	Demography	Dynamic changes of population numbers and overall social composition.	Rural population	inhabitants	Statistical data
6				Urban population	inhabitants	
7				Net migration per 1000 inhabitants	persons/year	
8	Health	Nutrition	Availability and quality of locally produced rice and rice products.	Self-supply of rice	months/year	Farmer survey
9		Infrastructure	Access to health infrastructure and the overall status of health infrastructure within the case study area.	Number of doctors per 1000 inhabitants	-	Statistical data
10				Hospital beds per 1000 inhabitants	-	
11	Personal well-being	Personal well-being	Subjective determinants of quality of life.	Personal satisfaction and happiness	scale from 1-10	Farmer survey
12		Work and life balance	The ability to combine work, family commitments and personal life.	Average working time during busy period	hours/day	
13				Average working time during other periods	hours/day	
14				Time spent for leisure and personal care	hours/day	
15	Environmental quality	Environmental quality	The health of the physical environment, focusing on pollution aspects.	Satisfaction with the quality of air	scale from 1-3[5]	Farmer survey
16				Satisfaction with the quality of natural waters	scale from 1-3[5]	
17				Satisfaction with the quality of household water	scale from 1-3[5]	

[5] 1 = not satisfied, 2 = satisfied, 3 = very satisfied

3.5 Linkages between the Provisioning Ecosystem Service Food Rice and Human Well-being

In this subchapter, the linkages between the provisioning ecosystem service food rice and human well-being are analyzed using the results of Subchapter 3.1 *Trends of indicators of human well-being* and Subchapter 3.2 *Trends of indicators of provisioning ecosystem service food rice*. In order to derive how the provisioning ecosystem service food rice and human well-being in the study regions are linked, the summaries of identified trends of human well-being indicators and ecosystem services food rice indicators in Subchapter 3.4 were used. Additionally, the comprehension gained from the discussion with the farmers and their comments during the survey conduction were taken into consideration. Five direct linkages and two indirect linkages between the provisioning ecosystem service food rice and human well-being categories were identified. Only one category of human well-being did not show a connection to the provisioning ecosystem service food rice in the research provinces.

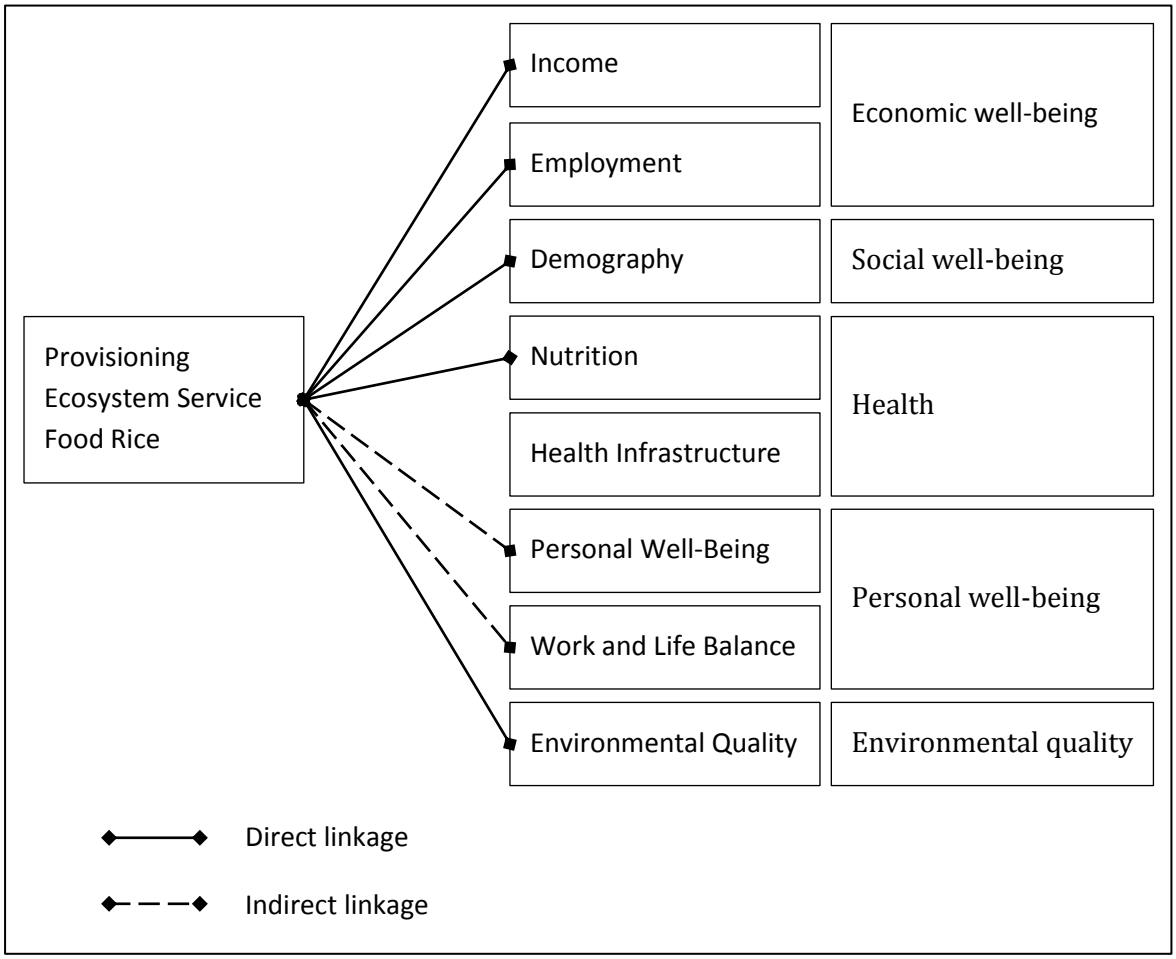


Figure 20: Conceptual linkages between the provisioning ecosystem service food rice and categories of human well-being of rice farmers (based on indicator analysis and comments of the farmers). Design by Lê and Kühn.

A detailed description of the linkages between the provisioning ecosystem service food rice and each human well-being category will be given hereinafter.

3.5.1 Income

During the ten years of the study period, the *yields of paddy* in Lao Cai and Tien Giang increased and correlated with an increment of *average annual income* of the rice farmers. In addition, the *savings rate of average annual income* of the farmers in Lao Cai and Tien Giang also increased. It means that the financial situation of the farmers became better and that they had more spare money for saving. Regarding the *share of annual income from rice*, the results showed a decrease in Tien Giang and were constant in Lao Cai. In Tien Giang, all of the farmers stated that they had other jobs than working in rice production. It means that higher yield of paddy was not the only factor that influenced the rising income. In Lao Cai, where rice did not give direct contribution to the *average annual income* of the farmers, it could be seen that due to the higher yield of paddy, the farmers had more rice for internal consumptions of their families. That led to the fact that they had less expenditure on buying rice for their families and more savings. Hence, the income of rice farmers has a direct linkage to the provisioning ecosystem service food rice. On the other hand, as it was reported by the farmers in Lao Cai and Tien Giang, more income enabled them to invest more in machinery equipment and fertilizers.

3.5.2 Employment

The *employment rate* in both provinces increased during the study period. It means that more jobs were available due to the economic growth of Lao Cai and Tien Giang. More *machinery use* reduced the work load of farmers on the fields. The interviewed farmers and officials mentioned that there were more new jobs in industrial and service sectors. In addition, they stated that the percentage of employment in rice agriculture declined in the last ten years. However, there were no statistical data indicating the *share of employees working in rice production*. Since the rising *yield of paddy* in combination with more *machinery use* led to a decrease in agricultural employment, the provisioning ecosystem service food rice had a negative effect on employment. The link of the provisioning ecosystem service food rice and employment could only be established based on the comments of the farmers and officials.

3.5.3 Demography

According to the statistical data, the number of *urban population* was expanding in both provinces while the *rural population* decreased in Lao Cai and stayed constant in Tien Giang. Moreover, the *net migration rate* was fluctuating. Obviously, there was an increasing trend of

urbanization in both provinces. The less demand of workers for rice production due to increase of machinery use is also a factor which allowed more people to leave the rural areas and move to the growing urban centers.

3.5.4 Nutrition

Higher *yield of paddy* allowed the farmers in Lao Cai and Tien Giang to supply their family with enough rice from their own fields. That explains why the nutrition category of human well-being could be directly linked to the provisioning ecosystem service food rice.

3.5.5 Health Infrastructure

From 2002 to 2012, the *number of doctors per 1000 inhabitants* and the *number of hospital beds per 1000 inhabitants* in Lao Cai and Tien Giang were increasing. However, it was not possible to derive a linkage between the health infrastructure category of human well-being and the provisioning ecosystem service food rice. It can be assumed that the improvement of health infrastructure was due to better policy implementation of the government.

3.5.6 Personal Well-being

The results of self-reported *personal satisfaction and happiness* showed that the farmers in Lao Cai and Tien Giang felt happier about their lives in the present than they did in the past. According to their judgment, the increase of *personal well-being* was mostly related to *average annual income.* The higher their incomes were, the happier they were. Additionally, the rice farmers mentioned a connection between their health status and their *personal satisfaction and happiness*. Therefore, an indirect linkage between the provisioning ecosystem service food rice and personal well-being could be revealed, as higher *yield of paddy* contributes to higher income of the farmers.

3.5.7 Work and Life Balance

The linkage between the work and life balance category and the provisioning ecosystem service food rice could be seen as indirect. The three indicators representing work and life balance were *average working time during busy period*, *average working time during other periods* and *time spent for leisure and personal care.* The results of the two indicators *average working time during busy period* and *average working time during other periods* remained the same in Lao Cai and Tien Giang in the ten years of the examination period. It indicated that there was no change in the working time of the rice farmers. However, the increase of the indicator *time spent for leisure and personal care* explained that even though the farmers had to spend the same amount of time on the fields, they still had more free time. Due to the fact

that their economic well-being increased (which is directly linked to the provisioning ecosystem service food rice), the farmers had to spend less time on their side jobs in order to earn more income.

3.5.8 Environmental Quality

Regarding the environmental quality category of human well-being, the trends of *satisfaction with the quality of air, satisfaction with the quality of natural waters* and *satisfaction with the quality of household water* in Tien Giang and Lao Cai were downgrading, except *satisfaction with the quality of air* of the farmers in Lao Cai remained constant. As it was reported by the farmers in Lao Cai and Tien Giang, one of the reasons that impaired the water quality was the increased *use of inorganic fertilizers* and pesticides. During the ten years of examination, more fertilizers were used on the field that had a negative impact on the quality of streams and ground water. Therefore, a direct linkage between the environment quality and the provisioning ecosystem service food rice could be drawn.

4. Discussion

This chapter will start with an outline of the obstacles encountered when conducting the study in the research regions. The second subchapter will discuss the most noticeable developments of the provisioning ecosystem service food rice and human well-being dimensions in Lao Cai and Tien Giang. Finally, the conceptualization of the linkages will be explained.

4.1 Data Reliability

4.1.1 Limitations of The Survey Conduction

As in the guideline of how to conduct a survey from the Rice Knowledge Bank (2009), the possible difficulties during the implementation of the survey were identified and anticipated beforehand. However, there were conundrums which occurred inevitably during the fieldwork. The intended design was to interview each individual farmer independently, so that they would not influence each other's answers. Due to time constrains and other limitations as well as misunderstandings in communication, in most occasions, the farmers were invited at the same time and were sitting together in one room during the interview sessions. Though each of the respondents was still asked separately, the others also took part in the interview by helping to answer the questions or discussing with the main respondent. Responding to the questions concerning income, yield of paddy or amount of fertilizers used on their fields may be an obstacle to some farmers. To several farmers it was difficult to recall their memory or they did not have the knowledge of the exact numbers. Sometimes the survey participants were uncomfortable to talk about these topics, or they were reluctant to give honest answers.

The second difficulty regarding organizational issues was the selection of interviewees. The process of choosing respondents was done with the help of contact persons in the study regions. Unfortunately, it turned out that many of the respondents were relatives or friends of the contact person. Since the rice farmers were not really selected randomly, they might be less representative for the whole population of rice farmers in the research areas. This applied more to Sa Pa, Lao Cai than to Cai Lay, Tien Giang. Even though the criteria of the target population of the survey were given to the contact persons, several contestants could not be taken into account, as they were not part of the target group. For instance, two respondents were from the same household. In Tien Giang, many of the interviewed farmers stopped producing rice since long and changed to fruit cultivation. That also explained why there were only 27 eligible samples in Tien Giang. On the other hand, in Sa Pa, the interviewer was obliged to pay a sum of money to each farmer who answered the survey. It was possibly another

reason why the contact persons mostly asked their cohorts to take part in the survey. In Tien Giang, the practice was different. Only small presents, without money, were given to the farmers after the interviews as the local experts of SRPPC had recommended. However, the survey was conducted in different villages with the assistance of different contact persons which helped to improve the representativeness of the farmer samples.

Time limit was also a hindrance during the survey conduction. Each interview was aimed to take place in 15 to 20 minutes. In Sapa, there were ten farmers being interviewed each day, five in the morning and five in the afternoon. There were other interviews by LEGATO project colleagues taking place in parallel in the same place. The farmers were asked to join both interviews. By reason of different interests and topics of the interviews, there was an urge for the interviewer to finish fast in order to exchange the respondents, when the other interview was completed. That put stress on both the interviewer and the interviewee to finish their talks fast. In Tien Giang, the survey was done at the harvesting time of the farmers. It caused some complication in finding enough farmers who had time to attend the interviews.

Another difficulty was the language barrier. In Sa Pa, the farmers were Hmong, Yao and Day people. Most of Hmong and Yao respondents did not show an advanced command of the Vietnamese language. It took long for the interviewer to explain the topic and the questions to the farmers in an easy-to-understand way. In some cases, the farmers did not speak any Vietnamese and the contact person had to help with translating and answering the questions. As the translation was not done by a professional interpreter, there is some subjectivity and uncertainty included in the translated answers and missing some information was not avoidable. In Cai Lay, the language obstruction was the difference between Southern and Northern dialects of Vietnamese as well as different colloquial languages of the regions. It happened that the responders did not understand the questions due to the Northern dialect of the interviewer and gave an answer which did not really relate to the questions. Being aware of the language obstacle, the interviewer attempted to prevent confusion by asking questions in simple language. When there were some doubts about the answer of the respondent, for example the answer was conflicting with the response of the previous questions or there was no concrete information in the answer, the interviewer was asking the question in more detail or in a different way so that as much information as possible could be gathered.

4.1.2 Future Outlook

The survey was intended to include the forecast of the rice farmers about the future development of the indicators for the year 2022. However, the farmers found the questions regarding future anticipation of the indicators too complex. It was difficult for them to imagine how the situation in the future would be. Therefore, it was decided to omit the future aspect of the indicators in the survey after the testing phase.

4.1.3 Availability of Statistical Data

Apart from the data which were extracted from the survey answers, statistical data were utilized for the indicator calculation. The statistical data availability was one of the main influencing factors on the decision of choosing indicators. Statistical data in Vietnam are often provided by the General Statistics Office of Vietnam or the statistics office of the provinces. The database of the GSO supplies the statistical data regarding all the topics mostly on big regional and national scales and not every topic is published on provincial scale. Moreover, the required statistical data of Lao Cai and Tien Giang were poorly available from the statistics offices and the governments of the two provinces. Therefore, adaptations of the indicators were made in order to take advantage of the obtainable statistical data.

4.2 Development Trends of Provisioning Ecosystem Service Food Rice and Human Well-being in Lao Cai and Tien Giang

4.2.1 Provisioning Ecosystem Service Food Rice

More rice output was the most remarkable development which was seen in Lao Cai from the survey. The average number of months that the rice farmers had enough rice from their own fields to supply their whole family was rising from 8.1 in 2002 to 10.6 in 2012. This showed that in Lao Cai the nutrient supply of the rice farmers was more secured. In addition, the farmers reported that their financial situation was better in 2012, which allowed them to buy more fertilizers for their rice terraces. It can be seen that more fertilizer input and higher yielding hybrid rice varieties contributed to the increase of rice production in Lao Cai. Yet the access to the locally supplied provisioning ecosystem service food rice of the farmers in Lao Cai was still relatively low in comparison to Tien Giang. Higher *yield of paddy*, more *machinery use* and higher *fertilizer input* capacitated an increase of the provisioning ecosystem service food rice in Tien Giang during the ten years of the study period.

The amount of all applied kinds of inorganic fertilizers' input per hectare, apart from phosphorous fertilizer, increased rapidly in Tien Giang during the study period. In Lao Cai, the

rice farmers tended to have the same practice of applying more fertilizer on the fields in 2012 than they did in 2002, except organic fertilizer input was reduced. Berg (2001) confirmed that higher fertilizer input happened due to the pressure of keeping up the high amount of rice output. It was verified by the interviewed farmers in both regions and Ives (2013) that extra income of farmers was often used to buy more pesticides and fertilizers. However, it should be taken into consideration that the excessive use of fertilizers could result in degradations of paddy yield (Nishio 2002, Young et al. 2002, Nomiles 2014).

Rice cultivation in Vietnam is highly labor-intensive (Dowling et al. 1998, UNEP 2003) and mostly practiced in small irrigated farms (UNEP, 2003). Even though there was an increasing trend of machinery use in Lao Cai, husking was done exclusively by hand and soiling was mostly operated by animal and human power. That was confirmed by Young et al. (2002), while comparing the spread of mechanical power technology in Vietnam and other neighboring countries. Machinery use in Vietnam was not as extensive as in other Southeast Asian countries (Young et al., 2002). Particularly in northern Vietnam, the operations of preparing the soil and threshing were still done by human and animal inputs (Young et al., 2002).

In Tien Giang, soiling, threshing and husking were done completely with the help of machinery. However, there were only 8 of 30 interviewed farmers using harvesting machines. The most important reason for the small rate of mechanization in harvesting is the small size of rice fields. The small area of paddy fields made it difficult to operate harvesters, because they were bulky and heavy and required better roads or pathways to pass across the canals and rivers (Truong, 2010). Moreover, as it was mentioned in Section 4.1.1, the survey in Tien Giang was done in villages that more farmers were planning to shift from rice cultivation to fruit tree plantations. The farmers claimed that fruit trees generated more profit and according to the development scheme of the Cai Lay district, the area to the South of Highway 1A was planned to focus on fruit trees such as durian, jackfruit, mango and rambutan (Tien Giang Government Portal, 2010). Therefore, the farmers in the research region of Tien Giang did not invest in costly harvesters.

4.2.2 Human Well-being

Generally, the human well-being of the rice farmers in Lao Cai and Tien Giang stepped up during the study period due to improvements in the dimensions of economic well-being, health and personal well-being. Oguz et al. (2013), Fahmi et al. (2013) and TNS Qual+ (2011) found out that income, health status and subjective well-being are amongst the key

influencing factors of human well-being, even though the three studies were based on different population target groups.

Regarding personal well-being, the results of the rice farmers in two study regions were closely connected to their income. The study of Diener et al. (1992) showed the same pattern of a strong connection between life satisfaction and wealth across nations. A similar trend can be found in Fahmi et al. (2012), who also mentioned that factors such as income and employment affected human well-being of farmers in Malaysia.

Health was ranked the most important influence to human well-being by TNS Qual+ (2011) and Oguz (2013), similarly the access to health infrastructure was important to the human well-being of the farmers in the research regions. Concerning the work-life balance, rice farmers were satisfied when they had more free time in 2012. Achieving a balance between work and life or taking part in leisure activities can help to reduce stress, depression and enhance positive moods (Randall, 2013).

Apart from private waste water, garbage and other sources, pesticides were mentioned by the farmers in both provinces as a pollution source of natural waters. Lamers et al. (2011) proved that pesticide use in rice fields in mountainous area of Vietnam posed a serious environment threat, especial to surface-and groundwater. Even though the farmers mentioned that they were aware of the impacts of excessive pesticide use on the water quality, yet a large quantity of pesticide was put on the fields (Pham, 2011).

4.3 Conceptualization of Linkages between Provisioning Ecosystem Service Food Rice and Human Well-being in Lao Cai and Tien Giang

The conceptual model in Figure 21 was developed based on the discussion of provisioning ecosystem service food rice and human well-being of the rice farmers in the two study regions. Rice field ecosystems supply the provisioning ecosystem service food rice which connects to human well-being in various dimensions. A direct influence of the provisioning ecosystem service food rice on the following human well-being dimensions could be established: *environmental quality, economic well-being, personal well-being, social well-being* and *health*.

Rice cultivation has negative impacts on the environment and the farmers' health (Roger and Joulian, 1999). Extravagant use of pesticides and fertilizers in current management practices of the rice farmers results in damage to public health and environmental quality through leakages and runoffs from the fields (Thuy et al. 2012). Development of the rice sector can increase social well-being of farmers (Africa Rice, 2013) or shortages of rice in many developing

countries can have a negative impact on social well-being (Wang and Valent, 2009). Regarding the relation of economic well-being and the provisioning ecosystem service food rice, Keizrul bin Abdullah (2007) stated that improvements of productivity and surplus production enhanced the economic well-being of rural populations. On the other hand, higher economic well-being increases the rice production by more investment in machinery use, fertilizer input or higher quality rice varieties.

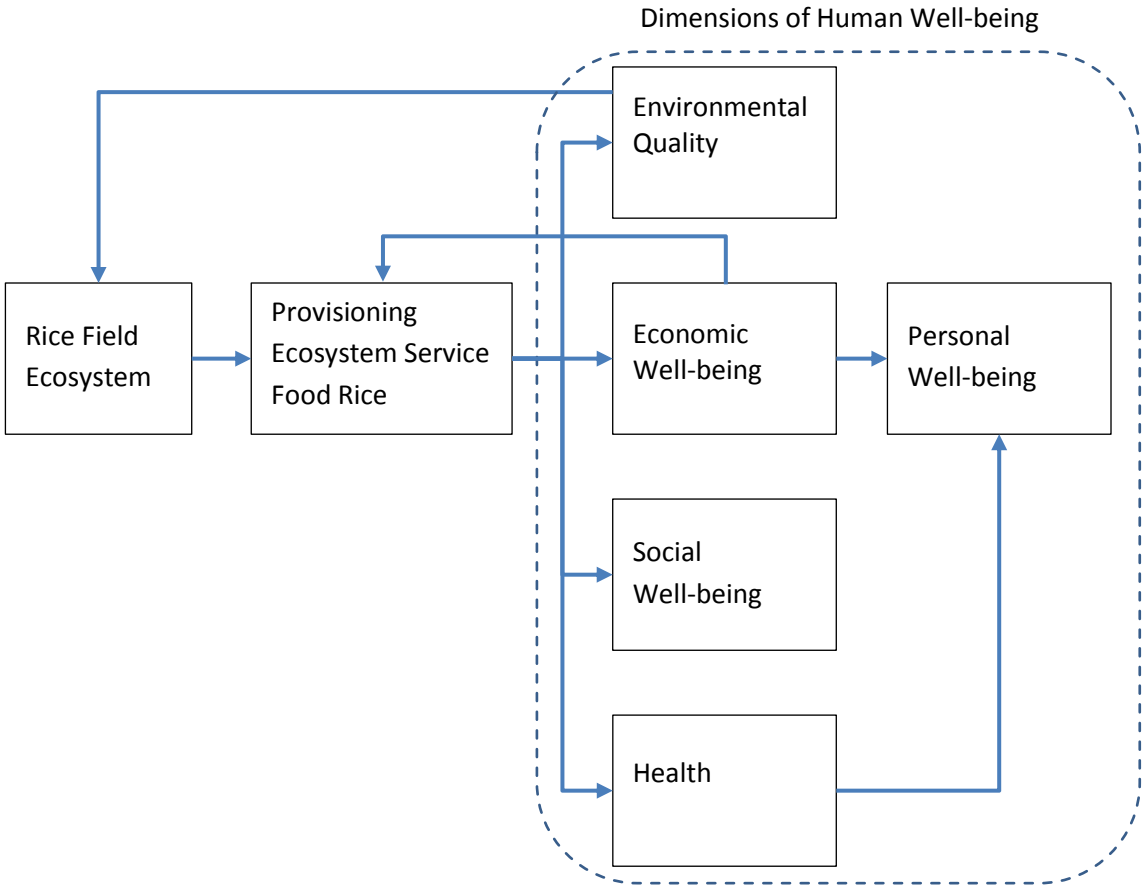


Figure 21: Conceptual model of linkages between the provisioning ecosystem service food rice and dimensions of human well-being in Lao Cai and Tien Giang (Design by Lê and Kühn).

The correlation between the provisioning ecosystem service food rice and human well-being can be seen as a two-way interaction. However, the scale of this study only allowed deriving a direct link from economic well-being to the provisioning ecosystem service food rice. Other dimensions of human well-being did not show a clear influence on the provisioning ecosystem service food rice.

This conceptual model was based on the results of this study and knowledge gained from the fieldtrip and literature reviews. There was no comparable case study that specified the linkages of the *provisioning ecosystem service food rice* to *human well-being*. Therefore, this conceptual model can be considered as a preliminary model which applies to the situation of

the two study regions Lao Cai and Tien Giang. It depicts the conceptual linkages that could be found in the scope of this pilot study. Of course further research and quantitative analysis of the linkages between the provisioning ecosystem service food rice and dimensions of human well-being is needed, to verify the results shown here.

5. Conclusion

The first main outcome of this study is the final indicators set to evaluate *human well-being* of rice farmers and the *provisioning ecosystem service food rice* in Lao Cai and Tien Giang. The proposed indicator set was developed using the studies *How's life?* (OECD, 2011) and *Conceptualizing the link between marine ecosystem services and human well-being: the case of offshore wind farming* (Busch et al., 2011) as guidelines. Implementation of the indicator set in the research regions showed some difficulties and obstacles which led to adaptations of the indicators. The adapted indicator set includes new indicators and omits the indicators which were proven to be inapplicable in the study areas. After the adaptation of the indicator set, all the proposed categories of human well-being were covered, except the education category. There was no available data from the survey and the statistical database related to the indicators of education. The adapted indicator set is a compromise between the ideal indicators set and the practical conditions found in the study regions.

The indicator set is applicable to quantify the trends of *human well-being* and the *provisioning ecosystem services food rice* in Lao Cai and Tien Giang. Economic well-being, health and personal well-being in both regions were increasing during the ten years of the study. The development of social well-being was not clear. However, there was an extension of urban population in both areas. The quality of the environment, i.e. natural water quality and air quality decreased in Lao Cai. In Tien Giang, the air quality remained the same from 2002 to 2012, while the natural water quality degraded. Even though there were obstructions in data collection, the obtained data from the survey and statistical database were valuable to derive the trends of the indicators. However, it is suggested that more detailed studies on each indicator should be conducted to enable the achievement of more profound insights.

In this study, the direct linkages between the *provisioning ecosystem services food rice* and the environmental quality, health, social well-being and economic well-being dimensions of human well-being were identified. The linkage of the *provisioning ecosystem services food rice* to personal well-being was indirect via economic well-being. The conceptual model of the linkages applies to the study regions condition. In order to generalize the conceptual model to other regions, it is proposed to carry out quantitative indicator assessments.

Regarding suggestions for the future development of Lao Cai and Tien Giang, it is recommended to take the rice farmers and their benefits as the focus of development in the regions. More systematic management of fertilizer and pesticide use should be implemented in parallel with transferring more knowledge of the paddy field ecosystem to the farmers.

Better understanding of farmers and effective guidelines from local authorities would lead to more sustainable development in the regions. In Lao Cai, the interviewed farmers were poor and only had limited accesses to equipment, inputs and training in rice cultivation. More effective support from the government is needed in the region. In Tien Giang, it is important to help the rice farmers balancing the rice production with the development of other plants that bring higher sources of income.

This study hopes to contribute its work to the indicator assessment of the LEGATO project as a small move forward in comprehending how ecosystem services and human well-being are influencing each other. Moreover, the findings of this study are promising to give a hand in the development toward more sustainable rice agriculture in Tien Giang and to ensure food security in Lao Cai.

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Appendices

Appendix A – English Version of the Questionnaire

Survey for Rice Farmers

Date, time:

Location:

Interviewer:

Interviewee:

Age:

Gender:

Number of persons in the household:

Member	Age	Occupation

Notes to interviewee:

Dear Interviewee,

We are conducting a research about human well-being and its correlation to the provisioning ecosystem service food rice. In order to carry out the research, we developed the questionnaire to gather your personal experiences and opinions. Thank you for your participation. I believe your input will be valuable to this research and in helping grow all of our professional practice. All of your answer will be kept confidential and only be used for scientific purposes.

We are interested in seeing the development of the rice output and human well-being. That is why we will ask you questions about the past, the present and your view about the future. The time step is about 10 years.

Our survey consists of 4 topics which concern: *environmental quality, rice provisioning, economic well-being and personal well-being*.

A- Environmental quality

1. How satisfied are you with the overall air quality?

	Not satisfied	Satisfied	Very satisfied
Past			
Present			

Note:

2. How satisfied are you with the water quality of natural waters in the area (rivers, lakes, ponds?

	Not satisfied	Satisfied	Very satisfied
Past			
Present			

Note:

3. Where do you get your household water from?

- For eating

	Well (drilled)	Well (dug)	From the pipe of water company	Rain water
Past				
Present				

- For hygiene purposes

	Well (drilled)	Well (dug)	From the pipe of water company	Rain water
Past				
Present				

4. How do you assess the quality of the household water?

	Not satisfied	Satisfied	Very satisfied
Past			
Present			

B- Rice provisioning

1. Do you have any kinds of machines that you use for rice production?

	Tractors	Harrows	Combined harvesters	Mill	Others
Past					
Present					

2. How much of your work in the fields do you do with machines?

a. Soiling

	Percentage
Past	
Present	

b. Harvesting

	Percentage
Past	
Present	

c. Threshing

	Percentage
Past	
Present	

d. Husking

	Percentage
Past	
Present	

3. How much fertilizer do you use on your fields?

	Organic	Phosphorous (P)	Nitrogen (N)	Potassium (K)	NPK
Past					
Present					

4. How much rice did you harvest in the respective year?
   - Past
   - Present
   - Harvesting area for past and present
   - Number of seed bags (only in Lao Cai)

5. Do you produce traditional aromatic rice varieties for your own consumption?

6. During busy period, do you have enough labor or do you hire additional workers?

	Enough	No, I have to hire additional workers
Past		
Present		

7. How many months of the year do you have enough rice for your family?

	Months
Past	
Present	

C- Economic well-being

1. Please indicate your average income of the respective year. If you do not want to give the accurate number, please indicate the development.

	VND
Past	
Present	

Comparison of present income to the past

	%
Present income in comparison to the past	

2. How much of the income mentioned came from rice? (%)

	Percentage
Past	
Present	
Future	

3. How much money could you save from the income you mentioned in question 1?

	Percentage
Past	
Present	

D- Personal well-being

1. How would you score your personal satisfaction and happiness?
   (1=not satisfied; 10=completely satisfied)

- Past:
- Present:
- Future:

2. If it is possible, what do you want to improve in your current life?

3. How many hours do you work per day in the busy period?

	Hours/day
Past	
Present	

4. How many hours do you work for the rice production per day in other times of the year?

	Hours/day
Past	
Present	

5. Do you have other jobs beside being rice farmer? If yes, please indicate.

6. How much free time do you have left per week when you don't have to work in any context? For your personal activities like resting, meeting with relatives, friends or neighbors; watching TV; having a walk, playing sports, reading newspapers…

	Hours/week
Past	
Present	

7. How are you satisfied with the amount of free time you have?

	Not satisfied	Satisfied	Very satisfied
Past			
Present			

8. Could you imagine your life in 10 years? How will it be like?

Thank you for your time and your answers.

Appendix B - Vietnamese Version of the Questionnaire

PHIẾU KHẢO SÁT

Ngày, tháng:

Địa điểm:

Người phỏng vấn:

Người được phỏng vấn:

Tuổi: Giới tính: Nam/ Nữ

Thông tin thành viên trong hộ gia đình

Thành viên trong gia đình	Độ tuổi	Trình độ học vấn	Nghề nghiệp

Kính thưa ông bà,

Chúng tôi đang thực hiện đề tài nghiên cứu về mối liên quan giữa điều kiện cuộc sống và dịch vụ liên quan đến hệ sinh thái mà cụ thể ở đây là cung cấp lúa gạo. Trong quá trình nghiên cứu, chúng tôi cần thực hiện một khảo sát nhỏ để thu thấp ý kiến và kinh nghiệm của ông bà. Chúng tôi xin cảm ơn sự giúp đỡ và hợp tác của ông bà. Chúng tôi tin rằng những thông tin mà ông bà cung cấp là tư liệu hữu ích cho đề tài nghiên cứu. Mọi câu trả lời của ông bà đều được bảo mật.

Chúng tôi muốn tìm hiểu sự tăng trưởng của sản lượng lúa gạo với điều kiện sống của con người. Do vậy, mỗi câu hỏi sẽ được đề cập theo 3 mốc thời gian: quá khứ, hiện tại và tương lai. Mỗi mốc thời gian này cách nhau khoảng 10 năm.

Các câu hỏi của chúng tôi được gói gọn trong 4 chủ đề: chất lượng môi trường, sản xuất lúa gạo, điều kiện kinh tế và điều kiện cá nhân.

A- Chất lượng môi trường

1. Mức độ hài lòng của ông bà về độ trong lành của không khí?

	Không hài lòng	Hài lòng	Rất hài lòng
Quá khứ			
Hiện tại			

Ghi chú:

2. Mức độ hài lòng của ông bà về chất lượng nguồn nước tự nhiên trong vùng (sông, hồ, ao)?

	Không hài lòng	Hài lòng	Rất hài lòng
Quá khứ			
Hiện tại			

Ghi chú:

3. Nước dùng cho sinh hoạt của gia đình được lấy chủ yếu từ nguồn nào?

- Ăn uống

	Giếng đào	Giếng khoan	Đường nước của nhà máy	Nước mưa	Nước từ nguồn tự nhiên
Quá khứ					
Hiện tại					

- Vệ sinh

	Bể ngầm	Giếng khoan	Đường nước của nhà máy	Nước mưa	Nguồn nước tự nhiên
Quá khứ					
Hiện tại					

4. Ông bà đánh giá thế nào về chất lượng nước dùng trong sinh hoạt?

	Không hài lòng	Hài lòng	Rất hài lòng
Quá khứ			
Hiện tại			

B- Sản xuất lúa gạo

1. Ông bà có sử dụng bất kỳ loại máy móc nào trong quá trình sản xuất lúa gạo không?

	Trâu	Máy cày bừa	Máy tuốt	Máy gặt đập	Máy xay xát	Máy khác (ghi rõ)
Quá khứ						
Hiện tại						

2. Ước tính khoảng bao nhiêu phần công việc trong quá trình sản xuất lúa gạo được thực hiện bằng máy móc?

- Cày, bừa

	%
Quá khứ	
Hiện tại	

- Gặt

	%
Quá khứ	
Hiện tại	

- Đập

	%
Quá khứ	
Hiện tại	

- Xay, xát

	%
Quá khứ	
Hiện tại	

3. Trung bình một vụ lúa, ông bà sử dụng bao nhiêu phân bón cho ruộng lúa của mình?

	Hữu cơ	Lân	Đạm/Ure	Kali	Tổng hợp
Quá khứ					
Hiện tại					

4. Năng suất gạo ông bà thu được là bao nhiêu?

- Quá khứ
- Hiện tại
- Diện tích
- Số bao lúa sử dụng

5. Ông bà có trồng loại gạo truyền thống nhưng sản lượng thấp để phục vụ cho nhu cầu của gia đình không?

6. Trong ngày mùa, ông bà có đủ nhân công không hay phải thuê thêm người?

	%
Quá khứ	
Hiện tại	

7. Bao nhiêu tháng trong năm ông bà có đủ gạo từ ruộng của gia đình để sử dụng trong việc ăn uống hàng ngày?

	%
Quá khứ	
Hiện tại	

C- Đời sống kinh tế

1. Ông bà có thể cho biết thu nhập bình quân một năm (tính bằng tiền mặt) của hộ gia đình (bao gồm tất cả các khoản thu nhập)?

	VND
Quá khứ	
Hiện tại	

So sánh thu nhập hiện tại với quá khứ

	%
Thu nhập hiện tại bằng bao nhiêu phần của quá khứ	

2. Trong tổng thu nhập ông bà đề cập ở câu hỏi 1, bao nhiêu phần trăm là từ lúa gạo?

	%
Quá khứ	
Hiện tại	

3. Trong tổng thu nhập ông bà đề cập ở câu hỏi 1, bao nhiêu phần trăm ông bà có thể để dành?

	%
Quá khứ	
Hiện tại	

D- Đời sống cá nhân

1. Ông bà có hài lòng với cuộc sống (về vật chất và tinh thần) của mình không? (1=hoàn toàn không hài lòng, 10= rất hài lòng)

Quá khứ	
Hiện tại	
Tương lai	

2. Nếu có thể thì ông bà muốn thay đổi điều gì trong cuộc sống hiện tại của mình?

3. Trong ngày mùa, ông bà phải làm việc bao nhiêu tiếng/ngày

	Số giờ
Quá khứ	
Hiện tại	

4. Ngoài ngày mùa, ông bà phải làm việc bao nhiêu tiếng/ngày?

	Số giờ
Quá khứ	
Hiện tại	

5. Ngoài làm ruộng ra, ông bà còn có công việc khác không? Nếu có, xin ghi rõ.

6. Ngoài giờ làm việc, ông bà có khoảng bao nhiêu thời gian nhàn rỗi để làm các việc khác như nghỉ ngơi, thăm hỏi họ hàng, làng xóm, xem ti vi, đi dạo, chơi thể thao…trong một ngày?

	Số giờ
Quá khứ	
Hiện tại	

7. Ông bà có hài lòng với lượng thời gian rỗi không?

	Không hài lòng	Hài lòng	Rất hài lòng
Quá khứ			
Hiện tại			

8. Ông bà hình dung về cuộc sống và tình hình sản xuất lúa gạo của gia đình trong 10 năm tới như thế nào?

Xin cảm ơn vì sự hợp tác của ông bà!

Declaration

Herewith, I declare that this thesis has been completed independently and unaided and that no other sources than the ones stated here have been used.

The submitted printed version of this work is identical with the one electronically saved and submitted on CD.

Furthermore, I declare that this work has never been submitted at any other time and anywhere else as a final thesis.

_____ _____

Date Signature