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The Combined Methodology of DPSIR Framework and Land Use Change for Exploring Smallholder Agriculture Security and Farmers Sustainable Livelihoods: A Case Study of Phaknamdang Subdistrict at the Upper Gulf of Thailand.

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Abstract

This paper proposes a novel methodology, an integrative systemic model, to explore the potential of climate variability and forces of change for smallholder agriculture security and farmers' sustainable livelihoods. The study method is designed to combine with two different assumptions: the DPSIR (Driving Forces, Pressure, State, Impact, and Response) framework for assessing local and nation dynamics force change factors, with land use change assessment for making decisions on environmental security, particularly in the coastal zone areas. The municipality of Phaknamdang Sub district (Samut Songkhram Province) located at the center of upper gulf of Thailand, has a community agriculture-based with almost of the households relying on the local ecological services system and natural capitals based approach. The data collection, both primary data (household survey, key informant interview, and focus group discussion) and secondary data (climatic, literature review), have been complied and rearranged with the application a Geographic Information System (GIS) method, facilitated the empirical data insight the indicators of Livelihood Vulnerability Index (LVI) associated with causal chains data collection from The DPSIR Framework.This study presents land use change on 4 different time periods from earlier in year 2001, 2006, 2009, 2012 and 2015. It highlights driving forces of the land use change (climate and non-climate variability and change with social forces of change), both the spatial and the temporal variability affecting ecological service phenomenon, with regards the grounded level of natural-based needed for agricultural security of community. The study method also provides the local community to explore alternatives role of agricultural activities, and their sustainable livelihood conditions.

Keywords: Coastal zone, DPSIR framework, land use change, LVI, smallholder agriculture

1 Introduction

Coastal ecosystems play essential roles in supporting ecological service and human sustainable livelihoods. As of 35% of the world's local agriculture lived and cultivate their farming activities in coastal zone. There are many situations in which coastal agricultural production makes an important contribution to the local economy or to national agricultural production. Under the risk of climate and other emerging societal issues, these dynamic forces of change often described as a creeping catastrophe of coastal ecological service sustainability. Local agriculture in coastal zone areas in Thailand, as in many countries, there are many reasons giving specific attention to the smallholder agriculture security and farmers' sustainable livelihoods.

1.1 Vulnerability assessment

The coastal zone and low lying areas appear to be most vulnerable to risk of climate change, e.g., ecological services, water temperatures, saline intrusion, and coastal erosion (Forbes DL, Rachold V, Kremer H, Lantuit H, 2011). Vulnerability of rain-fed agriculture is expected to increase with decreasing precipitation. Rapid population growth will raise food demand, and its impact on governmental decision, such as land policies, improvements in agricultural technologies and market oriented land-management, which can affect the efficiency and scale of cultivated land. These factors determine the vulnerability in food production systems and food security. On the global and local-scale, social dynamic (economic, social values, politic, and urban growth) are key drivers of increasing in exposure frequency and intensity of climatic extreme events will lead to increase the vulnerability of, water supply, human settlement, sanitation, urban sustainable assets and human wellbeing (Hanson S, Nicholls R, Ranger N, Hallegatte S, Corfee-Morlot J, et al., 2011). Where the impacts of extreme events (flood and drought) the agricultural production is affected by climate change which is linked to the smallholder agriculture security and farmers livelihoods (adapted from Hertel TW, Burke MB, Lobell DB, 2010).

Vulnerability assessment describes a diverse set of methods used to systematically integrate and examine interactions between humans and their physical and social surroundings. The field of climate vulnerability assessment has emerged to address the need to quantify how communities will adapt to changing environmental conditions. Various researchers have tried to bridge the gap between the social, natural, and physical sciences and contributed new methodologies that confront this challenge (Polsky C, Neff R, Yarnal B, 2007). Many of these rely heavily on the IPCC working definition of vulnerability, a function of exposure, sensitivity, and adaptive capacity (McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS, 2001).

Conceptually, vulnerability has been described as "a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (IPCC Third Assessment Report (McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS, 2001). Vulnerability is defined by a combination of social and environmental factors that could change over shorter or longer time spans. Changes in the social causes of vulnerability often happen much more rapidly than many environmental changes. Vulnerability to impacts is a multi-dimensional concept, "the degree to which a system is susceptible to or unable to cope with, adverse effects of climate change, including climate variability and extremes", encompassing bio-geophysical, economic, institutional and socio-cultural factors. Vulnerability is usually considered to be a function of a system's ability to cope with stress and shock (Smith K, 1992).

Vulnerability = *f* (Exposure, Sensitivity, Adaptive capacity)

Under the risk of climate change, vulnerability is a function of the character, magnitude and rate of climate variation to which a system is direct or indirect exposed, where people's sensitivity and their adaptive capacity. Exposure could include geographical location, especially related to high exposure to risks (i.e., people living in the areas of natural disasters such as drought or coastal areas and river basins affected by floods (Fussel HM, 2007).

Sensitivity and adaptive capacity are context-specific and vary from country to country, from community to community, among social groups and individuals, and over time in terms of its value, also according to its nature. Finally, adaptive capacity depends on access to resources that could help in responding to threats and exposures. The system's adaptive capacity i.e., the ability of a system to adjust with climate change to moderate potential damages, to take advantage of opportunities or to cope with the consequences then determines its vulnerability to these potential impacts.

Impacts of climate change pose very serious risks for countries, vital ecosystems, and other sectors including agriculture, forestry, health, local economic activities and biodiversity. In conjunction with other pressures, they could also exacerbate other serious local and regional challenges, such as poverty, poor healthcare, inequitable distribution of resources, diminishing ecological resiliency and energy insecurity. Global changes mainly, occur from anthropogenic emissions of greenhouse gases, such as carbon dioxide that results from the burning of fossil fuels, methane and nitrous oxide from multiple human activities. Vulnerability and adaptation assessments help to minimize the adverse impacts by means of deriving adaptation or mitigation strategies.

1.2 The DPSIR Framework

The framework supporting a systems approach is the Driving Forces – Pressures – State – Impacts – Responses (DPSIR) framework, which has been a valuable tool for organizing and communicating complex environmental issues. The DPSIR framework was developed by the European Environmental Agency (EEA, 1999) has been used by the United Nations (UNEP, 2007). The DPSIR framework is a systems-thinking framework that assumes cause-effect relationships between interacting components of social, economic, and environmental systems. The DPSIR framework has been used for many environmental resource applications, including management of agricultural systems (Kuldna et al. 2009; Binimelis et al. 2009), water resources (Mysiak et al. 2005; Borja et al. 2006), land and soil resources (Gisladottir and Stocking, 2005), biodiversity (Maxim et al. 2009; Omann et al. 2009) and marine resources (Mangi et al. 2007; Ojeda-Martinez et al. 2009; Yee et al. 2011; Nuttle and Fletcher 2013). The DPSIR framework also can be used to integrate social, cultural, and economic aspects of environmental and human livelihoods into a single framework (Yee et al. 2012). DPSIR has most commonly been used in the context of environmental management to link ecological and socioeconomic factors. The integration of DPSIR framework, based on the concept of causality chains for data analysis, and with the help of the application of the Geographic Information System (GIS) has the advantage of allowing the spatial visualization of the different indicators (Zandbergen, 1998). This integration method visualize complex information of different categories (UNEP/RIVM, 1994; RIVM, 1995).

This paper proposes an integrative systemic model – The DPSIR Framework with the application of Geographic Information System (GIS) facilitated the empirical data insight the indicators of Livelihood Vulnerability Index (LVI). It was developed as a prescriptive model based on theoretical foundation of normative theory in combination with the observations of descriptive theory. The aims of this paper is to illustrate the practical application of the model proposed to the smallholder agriculture sustainable livelihoods of one local agricultural community, located at the center of the upper gulf of Thailand.

2 Methodology

The methodological approach of this paper grounded on the conceptual of an integrative systemic model **(Fig. 1)**, in which this paper proposed, was developed by integrating the DPSIR Framework associated with the help of Geographic Information System (GIS: through the software application of ArcGIS 10.1) to facilitate the empirical data collection and execution insight the indicators of Livelihood Vulnerability Index (LVI), and to capture the level of the smallholder agriculture security and farmers' sustainable livelihoods.

The model was designed into a single framework, to capture core concepts of fundamental ecological sustainability essential for agricultural security and farmers' sustainable livelihoods, including: natural capital, human well-being, incorporates environmental factors (climate variability) and social dynamic forces of change (economic, social norms and values, politic and regulation, technological change). The structure of the model developed follows a defined system logic categorizations to represent a paradigm shift that focuses on study aspects of complex issues. It is worth note that the DPSIR framework developed in this paper was designed as a prescriptive model and adapted from EEA, 2005; Smeets and Weterings, 1999; Waheed et al. 2009; Yee et al. 2011, 2012, 2015; Smith et al. 2012; Munns et al. 2015; Ojeda-Martinez et al. 2009; Joffe and Mindell, 2006; Bradley et al. 2013; Odermatt 2004; Knol et al. 2010; Giupponi 2007; and, Russell et al. 2011.

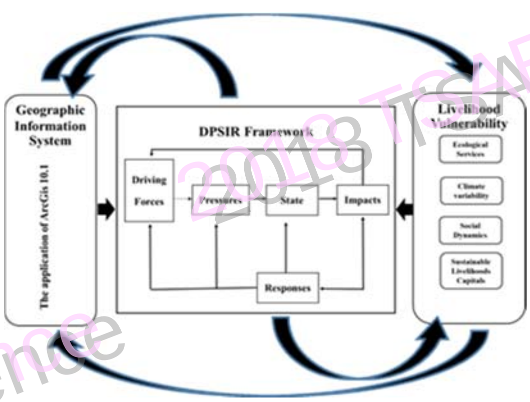

Figure 1 Conceptual of an innovative systemic model development

This paper illustrates the practical application from the model developed to the Phaknamdang Sub-District (PNK), Amphawa District, Samutsongkram Province located at the upper gulf of Thailand **(Fig 2).** The area is largely made up of local agriculture activity, which is depends upon the provision of the ecosystem services. The cultivation system are relying with local indigenous knowledge and simple crops production technique.

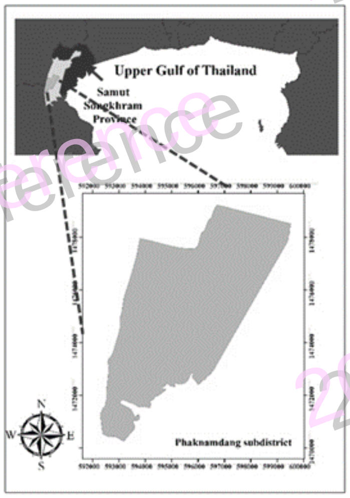

Figure 2 Location and geographic boundaries of the study area

3 Results and Discussion

At first, this study uses a land cover classification data set developed by ArcGIS software as the background data for spatially identifying the land use change during the study period. The data set is derived from Land Development Department (LDD). Following, the area percentage vector data are transformed into Matrixs followed the land use change 4 periods. However, the outputs of bottom-up vulnerability assessments, DPSIR, MA. Apart from using the results from participatory for analysis, bottom-up approaches can also accommodate quantifiable data like local weather data, downscaled climate simulations and data gathered through socio-economic household surveys.

3.1 Land Use Change

The landuse changes in the study area from 2001 to 2015 **(Table 1, Fig 3)** were characterized by a general increase of aquatic land, with a decrease in cultivated land. Factory area recorded the most significant expansion, being the result of rapid nearly economics provinces (Ratchaburi Province, Samutsakorn Province)

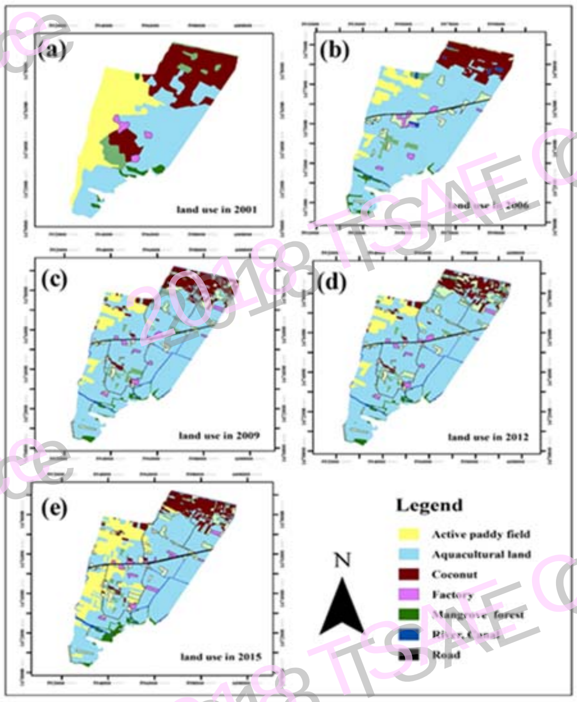

Figure 3 Landuse patterns of the PNK in 2001 (a), Landuse patterns of the PNK in 2006 (b), Landuse patterns of the PNK in 2009 (c), Landuse patterns of the PNK in 2012 (d), and Landuse patterns of the PNK in 2015 (e)

Figure 4 Agricultural activity and human activities, which indirectly exert influences on Land Use Change in Phaknamdang Sub District

Table 1 Land Use change during 2001-2015 (*Unit* km^2)

Land use type	2001	2006	2009	2012	2015	Change rate during 2001-2015
Active paddy field	7.96	↓2.02	↓1.90	↓1.87	↑5.45	-31.53
Aquacultural land	13.83	↑21.96	↓21.52	↑21.68	↓17.74	28.27.
Coconut	7.88	↓3.71	↓2.91	↓2.18	↑2.86	-63.70
Factory	0.48	↓0.43	↑0.49	↔0.49	↑0.59	22.91
Mangrove forest	0.54	↑0.56	↓0.52	↔0.52	↑0.72	33.33
River,canal	-	↑0.28	↑0.30	↔0.30	↑0.34	100
Road	-	↑0.20	↑0.27	↔0.27	↑0.34	100

Note *Change rate during (R) 2001-2015 is calculated based on following formula: R = (B - A)/A × 100 %:A represents the area of each type of land in 2001, and B represents the area of each type of land in 2015

Table 2 Shown the DPSIR in agricultural in Phaknamdang Sub District

	Driving Forces (Development and Human needs)	Pressures (Use of land and Human activities)	States (Spatial state of Land)	Impacts (Change and Resilience)
Land use in 2001	•Fisheries and livestock expansion continued from abroad.		•The overall agricultural sector slowed down.	• The impact Of droughts • Crops- price low.
Land use in 2006	•The expansion of the industrial zone in Ratchaburi and Samut sakhon. •Agricultural productivity to support the processing of the industry.	•The promotion of shrimp for export •The invasion area for farming shrimp.	• Agricultural Depression • Economic Recession • Labour transmigrate	• Mangrove Forest is degradation • Soil degradatio
Land use in 2009	• Policy to support rice farmers. • Asset capitalization policy.	• Land use change	• Change and ownership	• Flood and drought
Land use in 2012:15	• Land Allocation for farmers	• Support young generation farmers	• Land tenure and land use policy.	• Rice disease and pests are resulted from the impact of climate change.

4 Conclusions

Exploration on the DPSIR of LUC on Ecosystem Provisioning Services

Factors driving changes in agricultural: Based on the spatial change, the analysis categorizes the determining factors that affected agricultural is divided into two parts. The first part examines changes in agricultural that were driven by external factors. The second part examines land use changes that were brought about by internal factors, as following details.

Land use changes driven by external factors: Since, Thailand's agricultural policies have continuously evolved, and affected a wide range of domestic agricultural activities, which can be categorized into four groups of policy change.

The first group was 2 key instances of policy changes caused by the technical reasons, e.g., the prohibition of low salinity shrimp farming in inland freshwater areas. The change occurred after a series of technical reports that leaking saline water from shrimp ponds had damaged rice fields in the country's central region, and affecting the problem of rice-growing communities.

The second group of changes in agricultural policy was triggered by social conditions. The policy for sourcing water for farmers changed from construction of large dams or other large sources to construction of small-scale sources. Such a policy approach has later been adopted in other regions of the country and has continued till dated.

The third group concerned policy changes that was caused by government changes, which led to new policies initiated by subsequent ruling parties. There were five instances in this category, land ownership rights, land allocation for farmers, land tenure and land use policy, asset capitalization policy, and policy to support rice farmers.

The fourth group of policy changes was driven by government budget issues. The government was not able to accommodate the needs of a large number of farmers for their infrastructure needs due to budget constraints.

3) initiated by politics (e.g., ruling parties, administration disregarding old policy, and 4) driven by financial matters, i.e., government fiscal budget issues.

Land use changes driven by internal factors: The key internal factors involve farmers' changing lifestyle preferences, environmental values and extent the quality of local participation in planning. Together, land use changes are mainly caused by local agricultures activities, which lead to the major driving force of the local ecosystem service security.

The Systemic DPSIR framework application

In application, the Systemic DPSIR framework has distinguishes social, economic and environmental factors to category and provides a generic process that applied to the system of interest or the system of this study – that is smallholder farmer agriculture security and farmers' sustainable livelihoods, and other key-related agencies sustainable agriculture decision contexts. In doing this, the model is intended to serve as a researcher's field research tool of data collection, together for the facilitator and note-taker to apply during a DPSIR focus group workshop elicitation, and briefly describes as follows:

Collecting and Analyzing Relevant Data.

1 Driving Forces, Driving forces (Box 5.1 in Fig. 5) are the factors that motivate farmer's activities and fulfill their basic needs, which have been consistently identified as the necessary conditions and materials for a good life, good health, good social relations and security. It describes the community's demographic, and economic activities, and divided into two categories economic sectors and social driving forces.

1.1 Economic Driving Forces fulfill local community's needs for food and raw materials, water resources, culture, education (primary / secondary / universities), security, shelter, local hospital, social groups, public health agencies, outreach groups, and infrastructure (manufacturing and trade, transportation, construction, finance and insurance, industries, utilities, technical services).

1.2 Social Driving Forces: Humans live together in organized communities with shared traditions, and values. Social driving forces fulfill human needs for social relations / groups, equity (e.g., fairness of opportunities in a community, accessibility the education, health systems, jobs opportunity), governance (e.g., type of government and characteristics voting patterns of community), and cultural identity (e.g., history, social and cultural attitudes). Social driving forces broadly capture the suite of social, community, and political characteristics that influence the structure and function of economic sectors, as well as act as key determinants of human wellbeing

2. Pressures: Pressures (Box 5.2 in Fig. 5) are defined as farmers activities, derived from the functioning of Social and Economic Driving Forces that induce changes in the environment, or behaviors that can influence farmers livelihoods, which fall into two classes include:

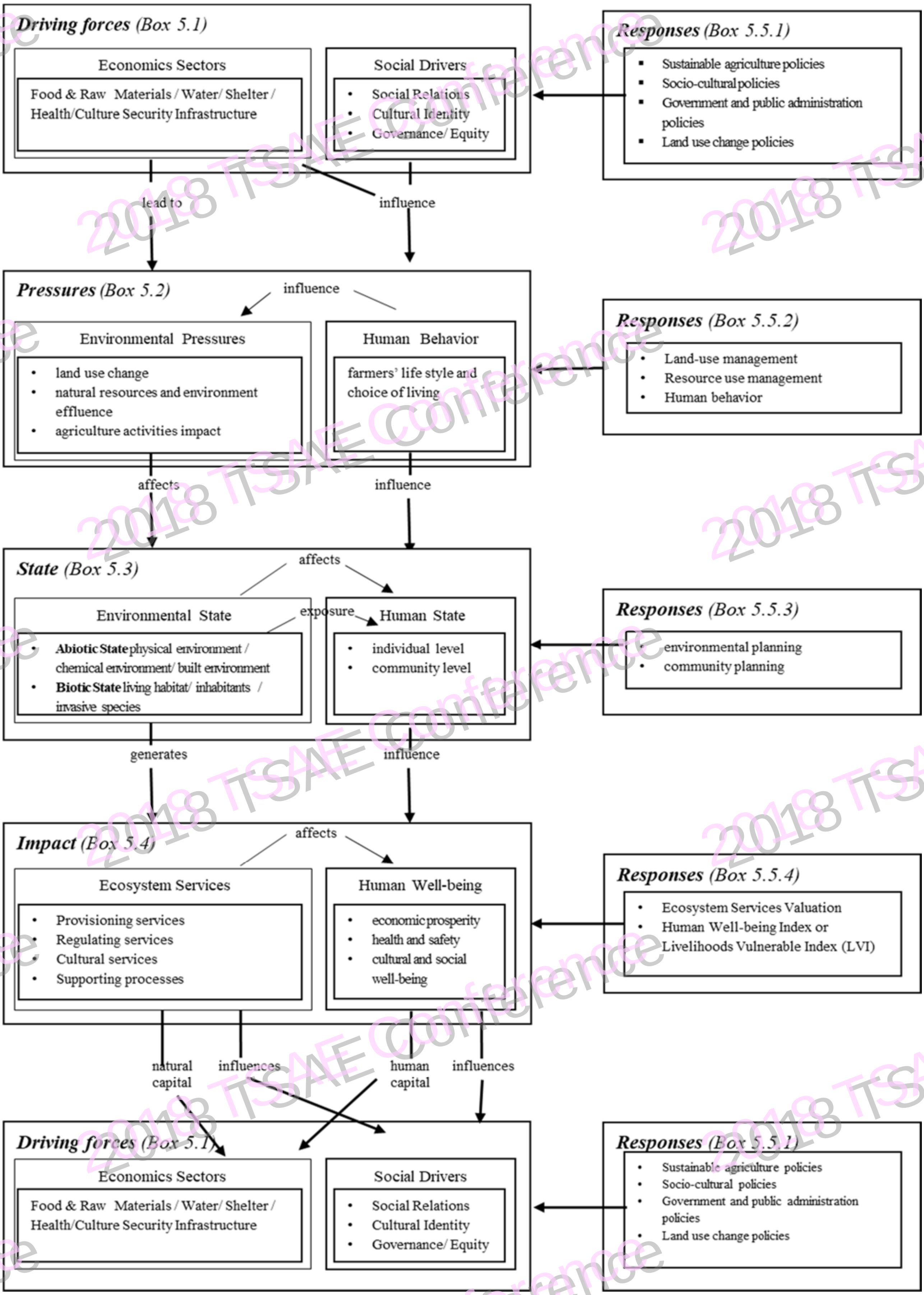

Figure 5 Shown the Systemic DPSIR framework application

2.1 Environmental Pressures: Environmental Pressures consider the environmental side, identifying a particular farmer's activity as a Pressure implies a causal relationship between the farmer's activity and local environmental change, Environmental Pressures include three sub categories, 1) land use change (e.g., alterations of the natural landscape, deforestation), 2) natural resources and environment effluence (agricultural/urban run-off, fertilizers/chemicals, wastewater discharges, solid waste disposal), and, 3) agriculture activities impact ecological security (release of non-native species (animal / crops), creation of artificial habitat, over harvesting).

2.2 Human Behavior Pressures: Normally, human behavior can influence human health independent of environmental pressures, which influence the physical condition of the environment. In this paper specifically define human behaviors, as with all pressures, as farmers' activities that can increase the chances of developing a disease, disability / syndrome, in regarding to the farmers' life style and choice of living (e.g., personal consumption behaviors, transportation, housing choice, traveling patterns, resource use and recycling)

3 State: State (Box 5.3 in Fig. 5) are defined as the level of stability or un-sustainability of the 1) natural and built environment, and human systems (e.g., population level and individual attributes).

3.1 Environmental State: Environmental State refers to all of the physical, chemical and biological components of the natural and built environment, which categorized as:

Abiotic State includes the non-living chemical and physical factors in the environment as well as the built environment (man-made structures), including 1) physical environment (e.g., climate, precipitation, storms and hurricanes, drought, flood, and fire), 2) chemical environment, and (e.g., nutrients, pH, atmospheric CO2 levels, salinity), and 3) built environment or man-made physical structures (e.g., buildings, roadways, landfills, brownfields, parks)

Biotic State includes the biological components of the ecosystem and their interactions, including humans. In this study, the biological condition has been measured both individual and community levels, including: 1) living habitat, (e.g., forests, grasslands, agricultural lands, wetlands, freshwater lakes and streams, estuaries), 2) inhabitants, (e.g., insects, birds, cattle, poultry), and 3) invasive/non-native species. (e.g., plants, animals, insects)

3.2 Human Systems State: Human health means a state of complete physical, mental, and social well-being. Determinants of health include the structure and function of economic sectors (e.g. health services, education, policy-making), social driving forces (e.g., cultural identity), human behaviors (e.g., life style and mobility), the physical environment (e.g., green space, weather), and individual biology and genetics. As shown in Fig. 5, the interacting influence of *Driving Forces, Pressures*, and *Environmental State* on human state. *Human Systems State* may be measured by 1) individual level and (personal characteristics; life stage, age and sex, gender, socio-economic status) and 2) community level attributes (e.g., population /community distribution of age, economic status, race, education, public health status)

4 Impacts: As shown in Fig. 5 (Box 5.4), the relationship of changes in the quality and functioning of the ecosystem have an impact on the production of ecosystem goods and services, local agricultural security and ultimately farmers' sustainable livelihoods, include:

4.1 Ecosystem Services: Ecosystem goods and services have been variously defined as ecosystem processes, or the products of those processes that directly or indirectly benefit humans (Millennium Ecosystem Assessment), as follows describes:

- *Provisioning services* - the biological or products local communities obtained or harvested from ecosystems for their use (e.g., food, water, and as their agriculture's raw materials activities)
- *Regulating services* – the biophysical processes that regulate the ecosystem, including regulation of air quality, water quality, climate, and natural hazards
- *Cultural services* - the nonmaterial benefits farmers obtain from the ecological integrity of ecosystems through spiritual enrichment, recreation, and aesthetic experiences, including recreational and educational opportunities, aesthetic value, sense of place, and spiritual or religious value
- *Supporting processes* - biophysical processes that maintain the functioning of the ecosystem, and are necessary for the production of other ecosystem services (e.g., water cycling, and provision of food and habitat)

4.2 Human Well-being: Human Well-being is an abstract concept that captures a mixture of people's life circumstances and quantifies the degree of fulfillment of basic human needs for food, water, health, security, culture, and shelter, include, 1) economic prosperity (e.g., productivity, ability to work, income), 2) health and safety (e.g., life span, medical or insurance costs, sick days), and 3) cultural and social well-being (e.g., sense of belonging, community vibrancy)

5 Responses

In the DPSIR framework, *Responses* are actions taken by individuals or groups in society and government to prevent, compensate or adapt to changes in the state of the environment. In this perspective, a key benefit in using the DPSIR framework developed in this paper is that it explicitly includes an action or response component that can be taken at any level of the systemic causal feedback link, as following discussions:

5.1 Driving Forces-based Responses: Responses (Box 5.5.1 in Fig. 5) may seek to control Driving Forces through policies or economic decisions that directly influence sectors, including:

1) *Sustainable agriculture policies* (e.g., legislation, restrictions, and guidelines that pertain to sectors that harvest or extract natural resources, including: agricultural best management practices,

2) *Socio-cultural policies* (e.g., responses that impact the distribution and functioning of cultural sectors, including tourism, recreation, education, and social organizations,

3) *Government and public administration policies* (e.g., responses to improve the decision-making and enforcement abilities of government and key related agencies institutions), and,

4) *Land use change policies* are responses to improve the distribution and appropriate functioning of sectors (e.g., industrial, transportation, commercial, etc.)

5.2 Pressure-based Responses: Responses (Box 5.5.2 in Fig. 5) may also seek to control pressures through regulations or technology that limit social activities, or decisions designed to modify human behavior, including:

1) Land-use management which seeks to plan and control sustainable development of lands (e.g., land-use zoning, designation of natural resources protected areas, coastal zone management),

2) Resource use management which seeks to initiate regulations, policies, and actions designed to control the use of natural resources including through, including technological innovations which leads toward environmentally-sound practices through, limits on and pollution control,

3) Human behavior modification is an attempt by an individual and group of farmers to modify their sustainable agricultural activity,

5.3 State-based Responses: Responses (Box 5.5.3 in Fig. 5) may also directly impact the state of the environment, farmers' wellbeing through: *1) environmental planning* which seek to control the physical, chemical, and biological environment including (e.g., water quality monitoring, biological monitoring, natural resources protection), and *2) community planning* which seeks to modify the state of the community by promoting and implementing actions such as, •Homeowner assistance, •Expanded economic opportunities

5.4 Impact-based Responses: Responses (Box 5.5.4 in Fig. 5) may also be designed to quantify for local agriculture security and farmers condition on sustainable livelihoods (e.g., off-farm activities):

1) Ecosystem Services Valuation process seeks to maintain the ecosystem service, natural resources protection from risk of climate change, and,

2) Human Well-being Index or Livelihoods Vulnerable Index (LVI) is an effort to quantify the condition human-social-environment condition in term of local farmers' agricultural activity choices, policy options for enhancing local sustainable capitals and their wellbeing.

5 Summary

The challenges of smallholder farmer security and farmers livelihoods in coastal zone include understanding of ecological and social process, foresee how to anticipate driver of changes and managing the resilience of ecological services. These challenges require a method of ground-root problem identification to an effective addresses information about how decision-makers, scientists, and society and key-related agencies perceive and define the issues. It also require the simplification of method to illustrate all functions in complex coastal socio-ecological systems in exchange for increasing sustainable policy.

This paper provides a novel methodology with a flexible systemic model. It conceptualized as a prescriptive model to illustrate the application of a smallholder agriculture sustainable livelihoods of one local agricultural community. The strengthen of the methodology and model proposed in this paper are that it; enhances communication by simplifying the complex connections between humans and the environment.

The benefit of integration of GIS facilitated the empirical data insight the indicators of Livelihood Vulnerability Index (LVI) provides the results for further data communicating complex environmental issues, e.g. refining the type of data collections in regarding to other remote areas of study. The causal chains DPSIR framework applied in this study is useful for identifying potential key driver of changes, particularly when scientific knowledge and data are incomplete.

In this paper, through the application of the model developed, in creating a systematic DPSIR conceptual model it is useful to integrate agricultural sectors and re-categorize others to reflect farmers need to better capture certain issues relevant to their environmental management. In future, the data and information from the results and discussions of the study should be revise with in-depth study, in term of logical analysis, regarding to the LVI enhancing smallholder security and farmers' sustainable livelihoods.

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