WWF

REPORT

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GREEN ECONOMY MODELLING OF ECOSYSTEM SERVICES IN THE DAWNA TENASSERIM LANDSCAPE (DTL) ALONG THE 'ROAD TO DAWEI'

WWF-Greater Mekong

March, 2014

This document is a report developing a socioeconomic model for land use change around the proposed transport corridor between Bangkok and a planned deep sea port development at Dawei in Myanmar.

The purpose was to create a pilot model structure as background research in the first phase of a larger plan to develop a comprehensive analysis of socioeconomic outcomes under different scenarios of transport corridor construction standards and resultant land use change. These scenarios are articulated as:

- A No-road scenario, under which the construction of the road is halted. Simulations under this scenario are used as a reference to evaluate projected positive and negative impacts of road construction on the economy, society and environment. The No-road scenario assumes the continuation of historical and present trends.
- A Road scenario case that assumes the construction of the road between Kanchanaburi and the Thailand-Myanmar border, but no additional policies implemented to mitigate possible negative impacts on natural capital and ecosystems. Under this scenario, the full impact of road construction is projected on the economy, society and environment, considering the complex relations between land use changes, ecosystem services and socio-economic indicators.
- Two Green Economy scenarios, on top of the road scenario, that simulate additional interventions for the protection of natural capital, including investments in ecological agriculture practices to increase yield and reduce soil erosion; water efficiency in agriculture; and reforestation activities.

WWF are currently fundraising to advance the analysis to pilot testing stage on-the-ground in Myanmar.

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KnowlEdge Srl (KE) is a consulting company with international presence, supporting its clients in exploring socio-economic and environmental complexity to inform decision making for sustainability. KE is a leader in developing customized methodologies and tools for the elaboration of integrated strategies, action plans and investment programs for green economy/ green growth. This includes work in the context of climate adaptation and mitigation, with emphasis on reducing vulnerability and enhancing resilience.

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WWF is one of the world's largest and most experienced independent conservation organizations, with over 5 million supporters and a global network active in more than 100 countries.

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption.

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TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

ANS	Adjusted Net Savings
ASEAN	Association of Southeast Asian Nations
BAU	Business as usual
CLD	Causal Loop Diagram
CLRC	Construction Labor Research Council
DTL	Dawna Tenasserim Landscape
FAO	Food and Agriculture Organization
GE	Green Economy
GHG	Greenhouse gas
GM	Greater Mekong
InVEST	Integrated Valuation of Environmental Services and Trade-offs
IPSR	Institute for Population and Social Research
MoU	Memorandum of Understanding
SD	System Dynamics
SFM	Sustainable Forest Management
TEEB	The Economics of Ecosystems and Biodiversity
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WAVES	Wealth Accounting and the Evaluation of Ecosystem Services
WB	World Bank
WIP	Water Information Program

PREFACE

WWF is implementing a coordinated conservation strategy focusing on shared ecosystems and key conservation landscapes in the Lower Mekong region in partnership with regional governments, communities and companies. A key priority of this strategy is to build climate change resilience through integrated conservation and economic development planning and implementation, supporting the collaborative management of shared ecosystems, emphasizing the considerable benefits that collaboration can confer to regional resilience to climate change.

Other elements of WWF's conservation strategy include:

- Advocacy for a regional climate change agreement amongst the Lower Mekong country governments;
- Landscape-scale biodiversity and forest conservation targets;
- The maintenance of landscape integrity through integrated spatial planning and payment for ecosystem services mechanisms;
- Improved protected area management;
- Activities to keep the Mekong river and key tributaries free flowing; and
- The accelerated development of mechanisms to ensure sustainable financing for conservation in the region, perhaps catalysed via funding from GEF5/6 for a regional program.

WWF Greater Mekong (WWF-GM) has launched a new Green Economy Initiative to achieve the objectives set out in WWF's conservation plan. There is a critical lack of "hard" data and evidence of the value of natural capital. As a result, many decision-makers – private sector and public – remain unconvinced of the benefit to them of adopting approaches that would result in sustainable use and conservation of natural capital as a foundation for a s ustainable economic development.

WWF-GM green economies initiative aims to achieve an integrated approach to development that balances the various demands on these landscapes through mainstreaming natural capital in decision-making and implementing activities to green economies in the region. Key to this is making the case for the true value of biodiversity and ecosystem services and engaging with governments, business and communities to create opportunities that enhances and captures this value in tangible ways.

Improved articulation of the value of ecosystems and the services they provide should help ensure that these values are better integrated into policy decisions, economic development indicators, corporate accounting and private investment flows. We work with green economy partners to find ways so the countries of the Greater Mekong could enjoy much greater economic benefits from managing their natural resources sustainably, both in the short term as well as the future, rather than exploiting them just for short-term gain

Building on WWF's on-going integrated land use planning tools and ecosystem service assessments, the proposed project will develop and model sustainable economy scenarios at the site and regional levels to measure, value and account for the economic value of the Greater Mekong Subregion's natural capital and ensure these values are factored into policy/incentives design, legislation and decision-making. This work will be carried out through multi-stakeholder consultations, collaborating with researchers across the region and utilizing the tools, capacity and networks developed under the WWF-GM integrated land use planning, natural capital valuation and green economy activities.

EXECUTIVE SUMMARY

During a special meeting of ASEAN Foreign Ministers held in Singapore on May 19, 2008, the foreign ministers of Thailand and Myanmar signed a memorandum of understanding (MoU) on the development of the Dawei deep-sea port project. The project, which involves the construction of a road link from Dawei to Bangkok, is likely to have considerable impacts on land use, ecosystems and biodiversity in the Dawna Tenasserim Landscape (DTL), a mountainous region characterized by a tropical monsoon climate, abundant precipitation and forest.

This report describes a pilot project to design an integrated framework to inform and support land use planning. It analyses interaction of social, economic and environmental factors in shaping future land use needs through a transparent system dynamics simulation model and generates projections up to 2035 to analyse the short, medium and longer-term consequences of road construction on society and land use in the DTL, along the 'Road to Dawei'. The aim is to allow policymakers, land use planners and other interested stakeholder to test the multi-dimensional impact of green economy interventions aimed at improving sustainability in the area. Results are communicated in biophysical and economic terms, also including the valuation of natural capital (stocks, flows and ecosystem services). Though still in initial stages of development, this study has already helped understanding the key drivers of change in the area, identifying data collection needs, and defining their use to carry out a green economy analysis.

The green economy interventions simulated in this study focus on mitigating unsustainable trends resulting from deforestation for road construction, as well as from population growth (including both urban and agriculture land expansion). Reforestation and sustainable forest management practices, as well as investments in the use of ecological agricultural practices are two examples of the interventions analysed. The main results of the analysis show that:

- Greening the agriculture sector, one of the main growth sectors projected under the business as usual case, is likely to increase productivity and reduce water consumption, at the same time creating employment and improving livelihoods of local communities. Furthermore, the expansion of organic agriculture and the consequent reduction in the use of chemical fertilizers would prevent soil erosion and water pollution.
- The use of degraded and abandoned land for reforestation would allow to expand forest cover, thereby preserving key ecosystem services, such as regulatory, habitat and production functions. More specifically, reforestation is likely to help preserving the hydrological cycle, enhancing water retention, preventing river siltation and sedimentation, and eventually reducing impacts of floods on local communities and agricultural production. In addition, the adoption of sustainable forest management practices would contribute to preserve biodiversity, and mitigate climate change through higher carbon sequestration.
- The medium and longer-term cumulative impacts are likely to outweigh the short-term benefits of road construction. As a result, the upcoming land use plans and patters have a critical role in determining the health and sustainability of the ecosystem in the Dawna Tenasserim Landscape.

The advantages and disadvantages of each scenario and intervention are presented in the report and, while not being fully customized to the local context yet (due to lack of data and the need to further engage stakeholders in the development of the model), the analysis highlights how important land use planning can be, not only for the siting and construction of the road but also for maintaining ecological integrity after the transport corridor is built.

1. INTRODUCTION

During a special meeting of ASEAN Foreign Ministers held in Singapore on May 19, 2008, the foreign ministers of Thailand and Myanmar signed a memorandum of understanding on the development of the Dawei deep-sea port project. The project, which involves the construction of a road link from Dawei to Bangkok, is likely to have an impact on land use, ecosystems and biodiversity in the Dawna Tenasserim Landscape (DTL), a mountainous region characterized by a tropical monsoon climate, abundant precipitation and a heavy forest growth.

Based on these considerations, the WWF-Greater Mekong (WWF-GM) Programme Office, in collaboration with other national and international stakeholders, has conducted a study for the mapping and valuing of natural capital and ecosystem services in the concerned area. The objective of the study, conducted with the help of the InVEST (Integrated Valuation of Environmental Services and Trade-offs) modelling tool was to provide relevant data in support of decision-makers for the adoption of an integrated approach to land use planning (WWF, 2013a) (WWF, 2013b) (WWF, 2013c).

Moreover, WWF-GM has recently launched a new regional green economies initiative, which aims to encourage an integrated approach to development that balances the various demands on landscapes through mainstreaming natural capital in decision-making and implementing green economy interventions in the region. Key to success is making the case for the true value of biodiversity and ecosystem services and engaging with governments, business and communities to create opportunities that enhance and capture this value in tangible ways.

This study builds on WWF's on-going work on natural capital mapping, integrated land use planning and green economy policymaking, and seeks to assess economic, social and environmental impacts of road construction on the DTL, and identify relevant green economy policy interventions that would enhance the sustainable use and conservation of natural capital as a foundation for sustainable and inclusive economic development. In particular, the study focuses on the road construction project in the Thai area of the DTL affected by the construction of the highway, and focuses on the identification of feedback loops, delays and nonlinearity in order to properly map the socio-economic and environmental system analysed and inform decision making.

The realization of this study involves the creation of a customized simulation model, based on existing data (local, regional and, when applicable, global). The model, made of cross-sectoral modules, is used to project scenarios of action and inaction, and assess the impacts of green economy interventions. This is done by highlighting upcoming challenges, estimating the investment required to reach stated goals, the avoided costs, as well as jobs and income created. The results of a business as usual (BAU) case are compared with green economy scenarios. More specifically, the cross-sectoral impacts of sustainable forest management and ecological agricultural practices are assessed using a systemic and integrated approach. Emphasis is put on the synergies created across intervention options, to avoid side effects and make use of synergies. The results of this study point towards options that mitigate potential future risks, informing the creation of more detailed (vertically and horizontally) follow up green economy assessments.

2. THE DAWNA TENASSERIM LANDSCAPE (DTL) ALONG THE 'ROAD TO DAWEI'

2.1. Overview

Figure 1 : The study area

In 2008, the Dawei deep sea port project was approved as a joint effort of the governments of Thailand and Myanmar. The project involves the establishment of a port in Dawei, the "capital" of the Tanintharyi Division, the southernmost administrative region of Myanmar. Prior to the construction of the port, road transport infrastructure is being improved through the construction of a highway linking Dawei to Bangkok, and passing through the Dawna Tenasserim Landscape (DTL), an area particularly rich in biodiversity, extensively covered by forests, and thereby abundant in natural capital and ecosystem services.

The Dawei Project is currently in Phase 1, which involves the construction of a highway section between Kanchanaburi and Dawei. The geographical focus of the study is the Thai side of the road construction area, namely the one comprised between the town of Kanchanaburi and the Thailand-Myanmar border. The System Dynamics modelling methodology is adopted to identify, map and quantify the key drivers of the system and make projections of expected economic, social and environmental impacts of the construction work and resulting changes in land-use.

The assessment has been undertaken using data sets that are as complete, consistent, current and accurate as possible. In particular, the GIS data and analyses produced by WWF with InVEST (WWF, 2013a) (WWF, 2013b) (WWF, 2013c) are used as reference for model calibration and validation. However, the lack of sufficient socio-economic and environmental data for the specific area affected by road construction required the use of data from the entire Kanchanaburi region, derived from the 2009 Thailand Human Development Report (UNDP, 2010). Partly as a result of these limitations in data availability and quality, and the lack of extensive stakeholder consultation and involvement in the development of the model, the study should be considered exploratory, or a pilot project. On the other hand, the trends projected remain valid, as they focus on systemic relations across the key variables modelled and do not necessarily need extensive local data availability to be included in the model.

2.2. Ecosystem services and related challenges in the DTL

Ecosystem services have been defined by Daily as the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life (Daily, 1997). In particular, the publication of the Millennium Ecosystem Assessment spurred a much greater awareness of the links between ecosystem services and human wellbeing. And with the global dialogue on Green Economy over recent years, there is an increasing emphasis on the development, livelihood and human wellbeing outcomes of ecosystem conservation. According to the MEA framework, there are four basic categories of ecosystem services: provisioning, regulating, cultural and supporting services (MEA 2005). Together these generate inputs to primary productivity, vital life support services and economic production that are critical to human wellbeing and to the functioning of the economy. The abundance of natural capital in the DTL ensures the provision of key ecosystem services, which largely contribute to the local and regional economy and social well-being.

The explicit recognition of nature's role in economic production, prosperity and value creation is essential to enable the transition towards more sustainable development patterns. In the specific case of the Dawei Project, it is advisable to estimate the expected impact of infrastructure development on ecosystem services and natural capital in economic terms. Moreover, the consequences of natural capital losses for economic development, income, and the overall well-being of the population should be properly analysed and understood in order to encourage the implementation of mitigation measures as needed and desired. For example, the loss of forest cover is likely to impact several ecological functions in the DTL, including carbon storage, maintenance of soil fertility and nutrient discharge, regulation of the hydrological cycle, water and air purification, and maintenance of wildlife habitat. Forests are also linked to social and cultural values and benefits, such as recreation activities, traditional resource uses and spirituality.

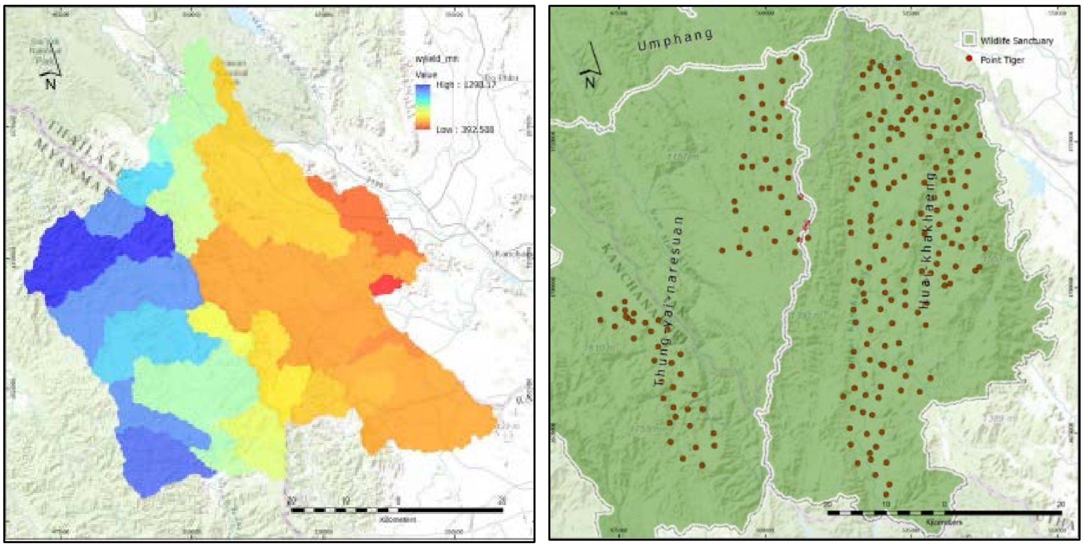

Figure 2 : Examples of ecosystem services being provided in the DTL: Current mean water yield map of the DTL (right) and tiger habitat and observable locations in Western Thailand (left) – Source: (WWF, 2013c)

The prevention of the unsustainable exploitation and consequent loss of forest should thus be a priority to ensure long-term economic sustainability for the Dawei project. An excessive expansion of population and economic activities (e.g. agriculture) may lead to uncontrolled deforestation, thereby increasing the exposure of the area to floods, landslides and soil erosion. Such impacts should be analysed also in light of possible climate change effects, such as fluctuating rainfall patterns, which could intensify pressures on natural resources, including rivers and forests, and further contribute to biodiversity loss and soil degradation.

2.3. Green economy opportunities

The potential impacts on natural capital and ecosystem services deriving from the construction of the highway in the Kanchanaburi region could be mitigated, and possibly offset, through the implementation of targeted green economy interventions in conjunction with the realization of the Dawei project. This would allow retention of the benefits created by the road (e.g., better access to markets), while mitigating any potentially negative impacts from degradation of natural capital.

The main principles of a green economy are described by UNEP, which considers the green economy as: "*An economy that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities*" (UNEP, 2011). At the operational level, the green economy is seen as one whose growth in income and employment is driven by investments that:

- Reduce carbon emissions and pollution;
- Enhance energy and resource efficiency;
- Prevent the loss of biodiversity and ecosystem services.

These include investments in human and social capital, and recognize the central position of human well-being and social equity (also related to environmental preservation) as core goals promoted by growth in income and employment.

In the DTL, a variety of green economy interventions could be implemented to encourage the sustainable management of natural resources and promote an ecosystem-based approach to development. The main green economy opportunities for the area include:

- The establishment of sustainable forest management (SFM) criteria and indicators in conjunction with investments in the reforestation of degraded and abandoned land. If managed in a sustainable way, forest resources and services can support the livelihoods of local communities and the economic growth of the area after the realization of the highway project, at the same time capturing and storing CO_2 emissions and mitigating climate change. Forest goods and services such as timber, fibre and other non-timber products can be used for the development of new green businesses, the creation of employment and the reduction of poverty.

- The development of organic agriculture, with the aim to increase food production, employment and income, while lowering land requirements and preserving natural resources and biodiversity through the use of ecological farming practices. Ecological agriculture would normally require investments in improved agricultural management practices (including organic fertilizers and pesticides), research and development, and possibly food processing (to avoid excessive post harvest losses). The expansion of organic agriculture is also likely to reduce water consumption, thereby lowering the stress on available surface and groundwater resources, and increasing the availability for residential use in the face of expected demographic growth.

3. GREEN ECONOMY MODELLING

3.1. Rationale for green economy interventions

The current understanding of economic growth is largely based on the neoclassical growth model developed by Robert Solow (1956). The patterns of development observed in the past indicate that economic growth has been driven by the exploitation natural capital and the production possibilities of economic and human capital, including technical progress (Solow 2003). Resource rich developing countries primarily rely on natural assets, such as land and other natural resources (e.g., timber, minerals and fossil fuels) to fuel economic growth; and natural resource utilisation has been shown to be influential as a continued driver of growth in later development phases too (Chambers and Guo, 2009).

Worth noting however, is the empirical evidence that suggests the growth rate of GDP during these phases tends to decline as economies become bigger (World Bank, 2013). This is observed in the case of Malaysia, Thailand and Vietnam, although not simultaneously. The economic performance of South East Asia often saw double-digit growth in the 1990's (see Figure 3). This period is characterized by rapid industrialization (e.g. for Thailand), favoured by strong demand for exports (fuelled by low production costs), and by the subsequent improvement in the provision of social services and infrastructure (e.g., for Malaysia). The development path of the last decades shows a decline in GDP growth, despite the continuous increase of investments (not only from abroad, but also domestic) and the strong commitment to further improve infrastructure. This trend is not surprising. China is showing similar figures, and most developed countries are only able to growth by 2% or 3% per year often driven by innovation (e.g., technology) and knowledge (e.g., education), as in the case of Europe and the United States (World Bank, 2013).

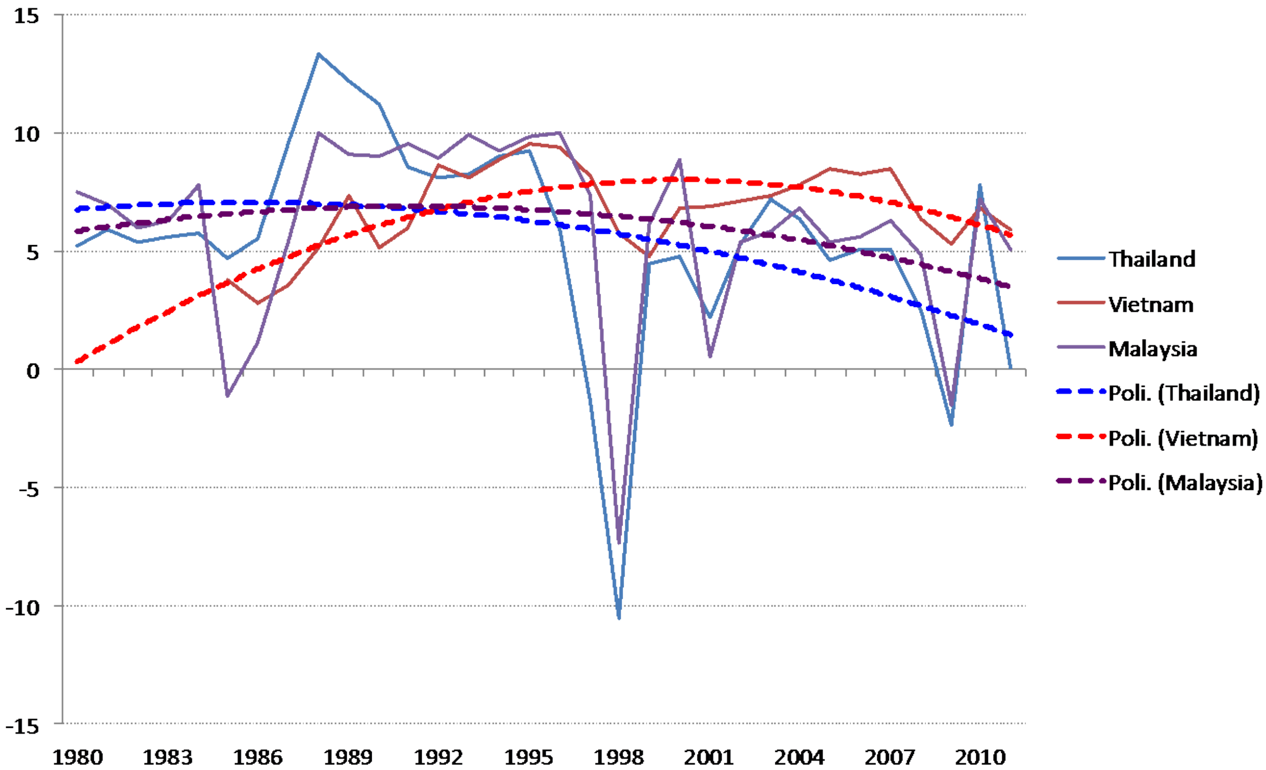

Figure 3 : GDP growth rate and its polynomial trend for Thailand, Vietnam and Malaysia (1980 – 2010) (World Bank, 2013).

Moreover, if we look more closely at the performance of the most successful economies in the world, we notice that they have almost entirely depleted their natural capital, are currently importing most basic resources, and are increasingly paying for the replacement of lost ecosystem services (e.g., water availability and purification) in addition to increased vulnerability to climatic changes (UNEP 2011).

South East Asia is moving in this direction, and the Greater Mekong region is not an exception. Cities are growing, infrastructure projects are making local markets more accessible for investments, and several issues faced by developed countries are becoming visible in the region too. Among others, the urban population is rapidly growing, traffic congestion is starting to heavily affect productivity, and air quality is deteriorating. Investments are needed to match the increasing request for social services, to allow businesses to flourish, and further stimulate economic growth, as done by all other developed economies (ADB 2012). While Solow and Stiglitz (1974) both show that sustained economic growth is possible so long as the reproducible factor of production (physical capital) can be substituted for exhaustible natural resources along the economy's balanced growth path, later research into the relationship between economic growth and environmental quality suggests that a simultaneous steady-state growth and a non-deteriorating environment are not only possible (Chambers and Guo, 2009) but likely the only pathway to truly sustainable development (UNEP 2011).

As shown in Figure 3, with BAU investments being the dominating cause for the economic growth observed in the past, an inflection point can be hypothesised. This inflection point can have several causes, one of which is the creation of externalities. In other words, while these investments have positive impacts, they also have some negative ones. Traffic congestion and air and water pollution among others, are examples of "hidden costs" to society that are not accounted for in official statistics (at least not economically), but that do have negative economic impacts (e.g., sick leave, health care costs) (Baumol and Oates, 1988).

Figure 4 shows graphically how green economy investments and interventions that support the conservation of natural capital while promoting an inclusive and resilient economy, would reduce the cost of externalities and effectively contribute to sustainable development. By 'greening' a higher share of total investment and supporting the creation of a more resilient economic system where natural capital is seen as an enabler rather than as a resource to exploit).

(a) Normal slowing down of GDP growth rate on BAU national economic growth trajectories, slowing in part due to the increasing cost of environmental externalities and degradation in natural capital.

(b) Total investment needs to increase over time in a BAU scenario to maintain economic growth gains, but typically the portion of green investment remains near constant or even declines.

(c) As natural capital degradation continues, the constant investment in green interventions actually indicates a decline in the share of green over total investments, reflecting an underinvestment in natural capital maintenance.

(d) Green economy or green growth concepts advocate for boosting the share of green investment as a share of total investment to compensate for historical underinvestment in natural capital, or as a means to green growth trajectories of emerging economies.

(e) The expected outcome of such green investment is an additional boost to GDP – or "green growth" driven by additional benefits and avoided costs –whereas, under BAU scenarios, real growth rates are declining.

While this concept may not apply to all contexts in the world or every individual country in the Southeast Asian region, it does represent the GDP growth trends of the region, as well as the nature of investments (for the most part BAU investments, including for instance road construction and urbanization).

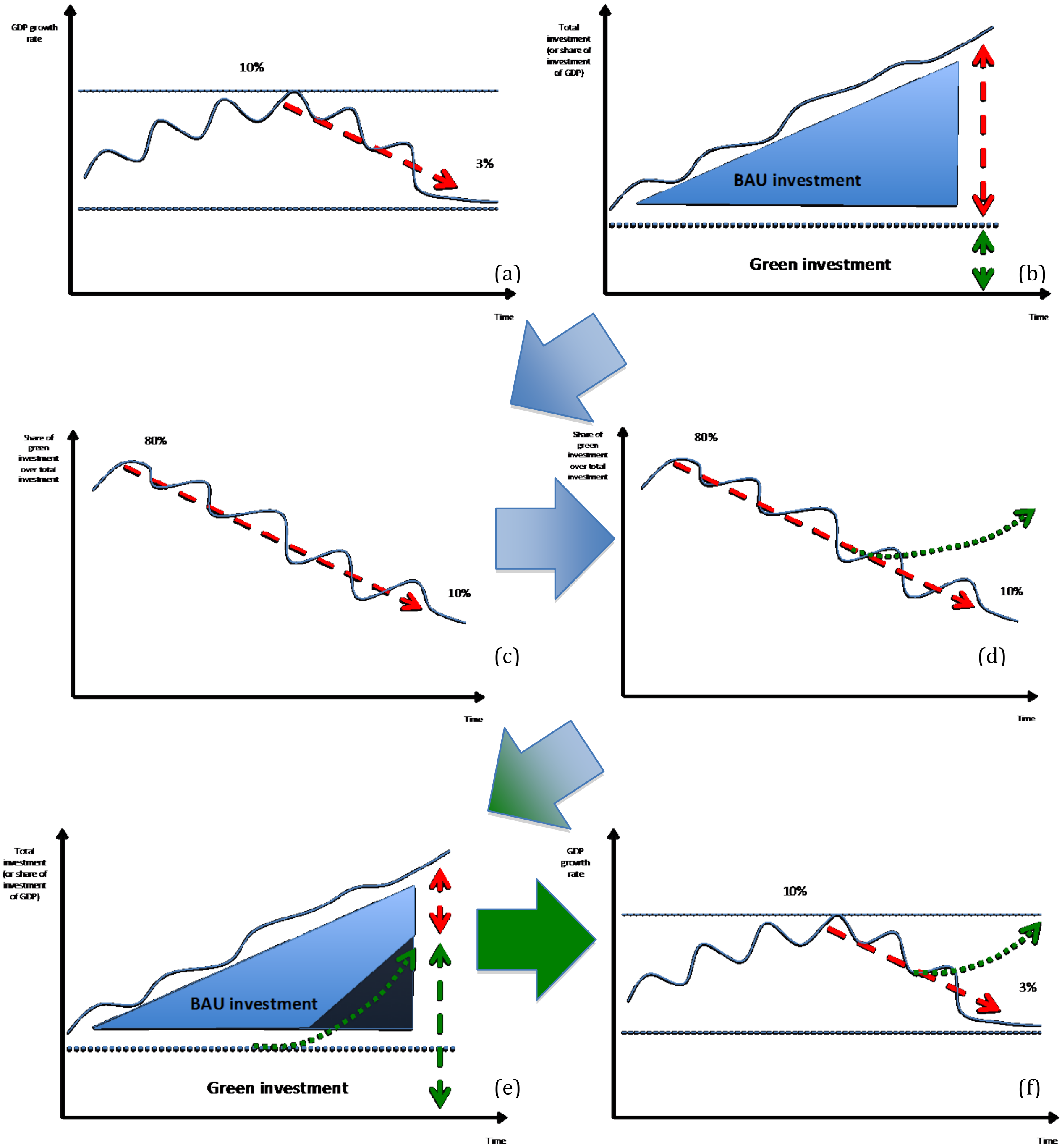

Figure 4: Observed patterns of economic development. BAU investments, leading to natural capital depletion, have increased externalities and costs to society and the economy. Green economy interventions can increase balance, by avoiding externalities and their costs and increasing benefits, while also increasing resilience.

3.2. Overview of the modelling approach

The analysis presented in this study entails the creation of a customized simulation model making use of existing local, regional and international statistics, as applicable. Data collection was carried out to gather the most suitable and valid data across sectors for inclusion in the model, with support form WWF staff and InVEST practitioners at Naresuan

University. The model is created to match available information and generate projections that could be directly compared with existing databases.

Systems thinking and System Dynamics modelling

Systems Thinking is the science of making reliable inferences about behaviour by developing an understanding of underlying structure of a system. ***System Dynamics*** aims to define causal relations, feedback loops, delays and non-linearity to represent the complex nature of systems; and to capture important and often counterintuitive insights about the ways systems operate in reality and what the consequences of enacting change in the system might be.

Systems Thinking has been applied to understanding how to change systems more effectively in public policy making and is used increasingly in modelling interactions between anthropogenic and natural systems to aid in choosing between alternative scenarios for actions or policy interventions (Ghaffarzadegan et al. 2010). Some effort has been devoted to applying these concepts to natural capital, and more specifically scenarios of climate change impacts (Costanza et al. 1993; 1998; 1997). More recently, UNEP, WWF and others have been exploring the applicability of this method in green economy themed analyses which seek to identify win-win policy solutions for sustainable development which generate economic growth gains and social equity through investment in maintaining ecosystem integrity, greening economic production (including energy) and improving resource efficiencies (UNEP 2011; WWF 2012). The latter applications aim to take into account the full benefits that can be gained by conserving natural capital (as stocks, flows and provision of ecosystem goods and services) for social, economic and environmental indicators.

The use of System Thinking and scenario analysis, with the creation of causal maps that capture the feedbacks and relationships between drivers of change in natural systems and outcomes of that change explicitly, has several purposes and advantages:

1. If stakeholder led, as best practice suggests it should be, System Dynamics modelling brings the ideas, knowledge and opinions of stakeholders together and allows all participants to reach a basic-to-advanced knowledge of the systemic properties of the issues being analysed. Having a shared insight related to a) natural systems and b) their interplay with socioeconomic systems is crucial for solving problems found in complex systems. In a good analysis, a proposed solution is not imposed on the system – or the people living within it. It should instead emerge from a better understanding of how the system 'works' and a substantive exchange with the actors who affect and live with change in that system.
2. It highlights the boundaries of the analysis, which can include a representation of the spatial dimensions of the system (important in conservation and land use) when coupled with spatial analysis and planning tools and/or focusing on impacts for human populations in particular locations, i.e. modelling scenarios of land use change, assessments of biophysical production of ecosystem services and how these may change with changes in the natural system.
3. In analysing the impacts of interventions, System Dynamics modelling supports an action-oriented approach that is particularly helpful in public policy research.
4. Scenarios help decision makers identify elements of uncertainty. Often scenario planning focuses on the analysis of the impact of external events on our system, forcing decision makers to elaborate concrete contingency plans and exit strategies. The analysis of the effectiveness of these plans, normally carried within a diversified team or group of stakeholders, allows decision makers to simultaneously consider the political, social, economic and environmental dimensions of the system.
5. Scenario analysis levels the paying field in that it does not extrapolate the past and does not expect past patterns (or the key drivers of past behaviour) to be still valid in the future. This methodology allows generating projections that do not extensively rely on historical data, or not as much as optimization and econometrics studies would require. In this respect, scenario analysis promotes innovative thinking, looking at the dynamic properties of the system in a systemic way, without excluding any potential system response (knowledge or experience) at priori.
6. Finally, scenario analysis creates expectations about future paths. As a result, indicators can be identified to monitor whether any of the observed paths is actually taking shape in reality (monitoring and evaluation). This allows decision makers to effectively and rigorously monitor the performance of the system.

Model structure

Using this approach, the aim is to create a pilot model in this project that – once fully deployed in a multi-stakeholder processes – can be used to analyse future trends emerging from scenarios of action and inaction regarding sustainable transport design and land use planning in the context of the 'Road to Dawei'. The model links spatial change to potential socioeconomic implications of different actions to manage that change. These socioeconomic impacts are assessed across sectors (social, economic and environmental) and actors (e.g., households, private sector and the government), within and across countries.

The phase of research described in this report is that of a design phase. A pilot model structure is created that describes the natural system along the route of the Bangkok-Dawei transport link including variables – and the interaction between these variables – that relate to the benefits from natural capital on human well-being. In following phases, the model will be tested and applied with strong stakeholder participation.

Summary of key structural parameters

- Focus is on the sectors and variables that are directly or indirectly influenced by the construction of the road between Kanchanaburi and the Thailand-Myanmar border.
- The simulation starts in the year 2007 and reaches 2035, allowing for historical behavioural validation over a period of approximately 5 years (depending on data availability).
- The benefits of different strategies to manage change in the natural system caused by different scenarios of road siting and design captured in the model include:
  - **Direct benefits** include employment generation (e.g., new jobs for installing and maintaining renewable energy infrastructure), improved access to energy and water, increased food security (e.g., as result of ecological agriculture practices), among others.
  - **Indirect benefits** include health (e.g., reduced occurrence of diseases linked to air or water pollution, adoption of healthy lifestyle), education (e.g., higher quality education and business skills resulting from capacity-building activities on innovative green techniques and technologies).

The model created for this study is focused on those sectors and variables that are directly or indirectly influenced by the construction of the road between Kanchanaburi and the Thailand-Myanmar border (about 80km of length), with particular attention to economic, social and environmental impacts on the concerned area (see Figure 5). The categories of these sectors and variables include:

1. **Social dynamics**. Structural changes in local populations are also influenced by the construction of the road, since the need for additional manpower for agriculture and construction works is likely to trigger a reduction in outmigration and growing immigration (for farmers and workers from neighboring areas, attracted by new employment opportunities). The creation of employment as a result of enhanced economic attractiveness of the area is considered also in terms of additional income generated. On the other hand, immigration and population growth lead to an increase in the demand for urban areas and agricultural land for domestic food production. In the model, land for urban development is derived from, in order of priority, degraded agriculture land, the area surrounding the new road, and forests.
2. **Agricultural practices.** A key environmental aspect considered in the model is the impact of unsustainable agricultural practices, such as the intensive use of chemical fertilizers, on soil quality. Despite chemical inputs are likely to boost productivity and production in the short-term, their medium to long-term effects on soil erosion and degradation are expected to threaten the sustainability of the sector, eventually reducing the productivity of agricultural land, with negative socio-economic consequences. As a result, decisions on the use of fertilizers and pesticides have repercussions across the various sectors represented in the model. A green economy investment in organic fertilizers and the development of ecological agriculture can be activated in the model to project impacts on soil quality, agricultural production, and employment.
3. **Natural capital stocks.** Construction works are set to start in 2013 and extend until 2018, the expected date of completion of the road. The land needed for the construction of the road is assumed to be primarily obtained through deforestation, thereby reducing forestland. Moreover, it is assumed (based on surveys created to support the InVEST analysis) that enhanced transport infrastructure has a positive effect on the economic attractiveness of the area, particularly for the cultivation and export of agricultural products. This produces a further increase in deforestation for the purposes of agricultural production.
4. **Ecosystem services.** The socio-economic dynamics and the change in land uses described above will have an influence on the integrity of natural systems in the locality. In particular, the model represents land use and

water demand and supply dynamics in the area, among others. The model focuses on a number of key ecosystem services (though these are not by any means the only ecosystem services being produced in this locality):

- *Water provisioning.* The demand for water is strongly influenced by population (residential water demand) and agricultural production (agriculture water demand).
- *Water flow regulation.* On the other hand, the availability of water is linked to the frequency and amount of precipitation (possibly impacted by climate change) and the quality of ecosystem services, including the role of forest in water flow regulation and flood prevention. In particular, deforestation is assumed to lead to an increase in the occurrence of floods when high precipitation events occur, which in turn cause the temporary decline of agricultural yield, as well as river siltation and sedimentation, eventually reducing surface water inflow. The introduction of reforestation policies would thus have a positive impact on the overall water availability for residential and agricultural uses, creating the enabling conditions for sustainable development.
- *Carbon sequestration.* The role of forests for carbon capture and storage is represented in the model, as well as their impact on biodiversity. In particular, the forest area is positively influencing the carbon stock stored in biomass. As a result, deforestation leads to a reduction in CO_2 absorbed and stored by forests. The economic value of carbon sequestration is also considered, and calculated on the basis of an average -and arbitrary- price per ton of CO_2 given the lack of local or even regional estimates. Projections of the economic value of, among others, annual carbon sequestration in the concerned area helps with improved understanding of the relation between the economy and ecosystem services -and vice versa-, and to quantify expected gains or losses deriving from different development paths and resulting land use scenarios.

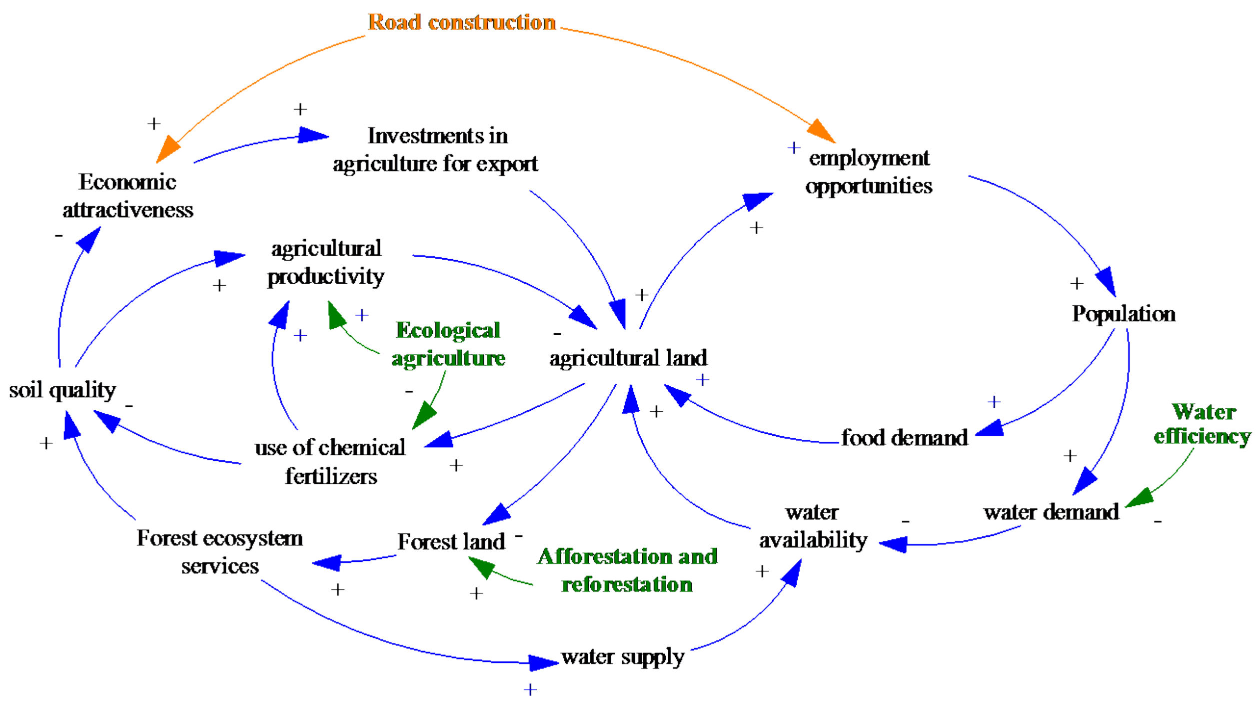

Figure 5 : Causal loop diagram (CLD) representing the cause-effect relations among key indicators analysed, and the effect of green economy policy options.

Data used

The valuation of natural capital in this study builds on the work being carried out by various organizations, global initiatives and research institutes. It is partial and by no means exhaustive, and it is presented to highlight the synergies that can be created by coupling the modelling work with the valuation of natural capital, especially in the context of planning and policymaking. Worth noting, we could not estimate the value of ecosystem services, due to the lack of data and the limited time frame of this study. On the other hand, this is possible, as presented in a similar study carried out for the Hearth of Borneo (Van Paddenburg, 2012). These studies include, among others:

- The Economics of Ecosystems and Biodiversity (TEEB), a global initiative that brings together expertise from ecology, economics and development to support the mainstreaming of biodiversity and ecosystem considerations into policy making (TEEB, 2010).
- Wealth Accounting and the Evaluation of Ecosystem Services (WAVES), a global partnership that aims to promote sustainable development by ensuring that the national accounts used to measure and plan for economic growth include the value of natural resources.
- The World Bank genuine savings indicators, or adjusted net savings (ANS), which are used to measure changes in wealth through savings, and account for changes in all assets depreciation of produced capital, including depletion of natural resources, and future losses owing to carbon emissions (World Bank, 2011).
- The green economy indicators being developed by UNEP to support the identification of worrying environmental trends and the formulation, assessment and evaluation of adequate and contextualized green economy policy interventions and investments (UNEP, 2012).

Figure 6 shows the main methodologies and models utilized in the study. InVEST, which generates spatial information and estimates natural capital and ecosystem services is used as input for estimated changes in natural capital stocks, i.e. forest land cover change, and resultant estimates of changing values in key ecosystem services (1). This information coupled with socio-economic analysis is used to create the map of the system (or Causal Loop Diagram) to identify the main drivers and impacts of land use change in the DTL region (2). System Dynamics methods require an integrated mathematical model (3) that incorporates the key drivers of change and impacts. This mathematical model is calibrated using InVEST's outputs, among others through validating the direction and magnitude of relationships between biophysical variables and ecosystem service variables, i.e. changes in surface water flow corresponding to hectares of forest lost in the DTL as a result of road construction. Finally, the result of the simulations generated with the System Dynamics model can be fed back into InVEST (or any land use change modelling software, i.e. Marxan) to visualize spatially the indirect and induced social, economic and environmental impacts of road construction. Weighing up the various impacts, the System Dynamics model could identify specific interventions on improved sustainable agricultural practices which could be tested for likely effectiveness in maintaining key ecosystem services in the InVEST models.

In other words, the results of the System Dynamics model could be used as scenario drivers for the other analysis approaches for land use change or valuing changes in ecosystem services as a result of changing land cover. This is an important value-added of the System Dynamics approach since InVEST only estimates the direct impacts of land use change on ecosystem services and not on other variables like population growth rates or specific action-oriented interventions

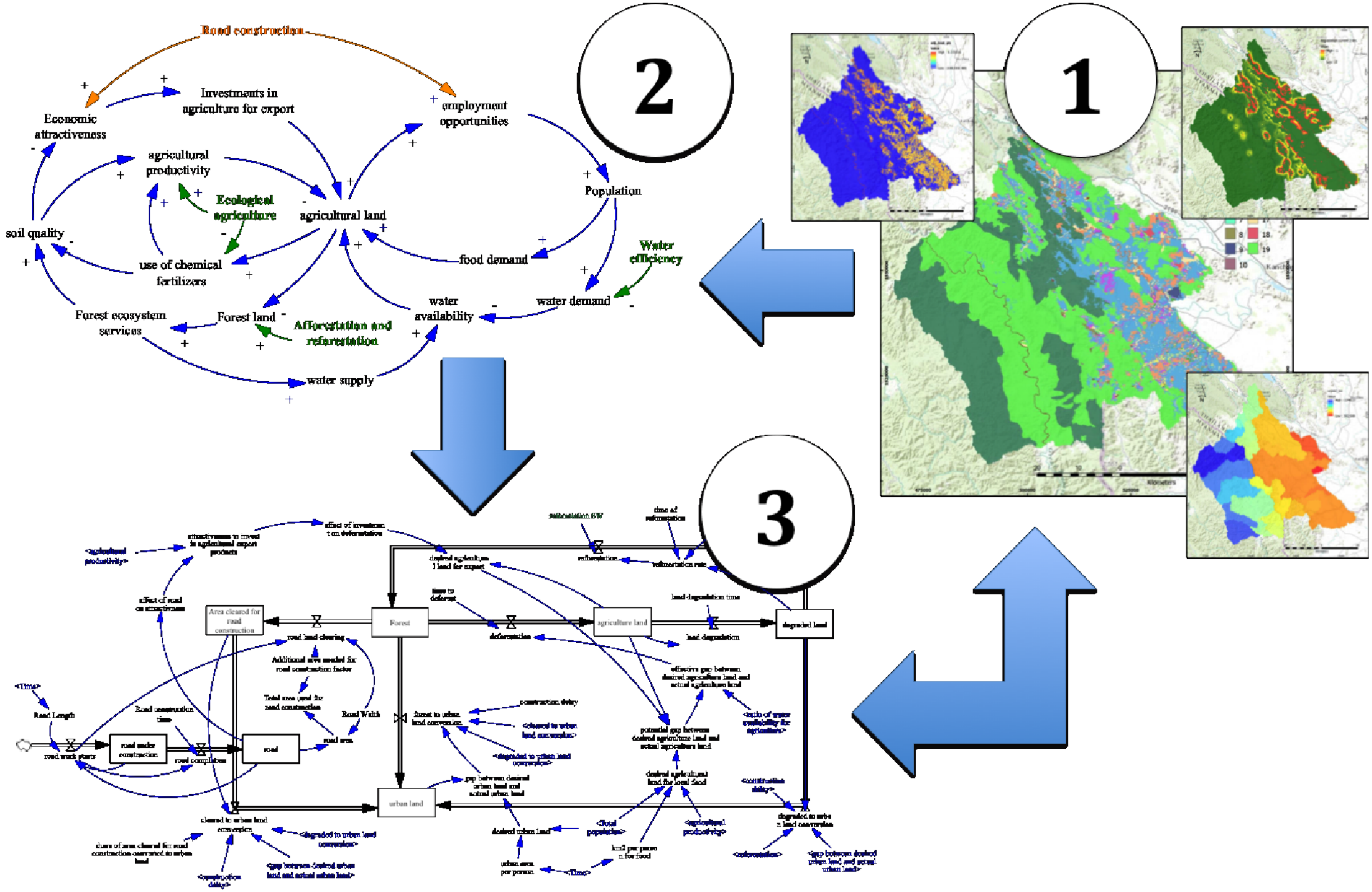

Figure 6: The main methodologies and models utilized in the study: InVEST, with spatial information (1); System Thinking, to identify key social, economic and environmental drivers of change (2); System Dynamics, to quantify scenarios with a systemic and integrated approach (3).

3.3. Assumptions

Various parameters and assumptions from available studies are used for the simulation of the baseline and alternative scenarios. All the assumptions used for the purpose of this study are listed in the following table.

Table 1: Parameters and assumptions used for model development

Land use	
Total area cleared for road construction	10.56 km^2, calculated as 3 times larger than actual road area (2.64 km^2) due to additional land clearing for construction purposes.
Forest land	Forestland is used for the construction of the road and for the expansion of agricultural land.
Urban land	Urban areas are built on degraded land. In case degraded land is not available, part of the area cleared for road construction is used for human settlement, up to 30% of its total. Any remaining need for urban land is fulfilled through deforestation.
Population	
Growth rate	The net population growth rate (birth minus death rate, excluding migration) is assumed to be 3%, based on demographic trends in the Kanchanaburi area (Indepth Network, 2013).
Out migration	An out migration rate of 5% is assumed for the BAU scenario. However, the construction of the road is assumed to drive a progressive decline of out migration, due to increased employment opportunities deriving from the improvement of transport infrastructure. The out migration flow would stop by the year 2025.
Water	
Average annual precipitation	1,500 mm/year (World Bank, 2013).
Average water use in agriculture	660 mm/ha/year (Water Resources System Research Unit, 2012)
Residential water demand/capita	The average amount of m^3 per person per year is 39.54m^3 (6,500 cubic meters for 60,000 villagers in Thailand, on average, per day) (WIP, 2013)
Agriculture	
Effect of road construction on agriculture attractiveness	Attractiveness would gradually increase since the starting of road construction works, reaching a four-fold increase after road completion.
Impact of investments in agriculture on deforestation	When attractiveness is at the maximum level, a 10% increase in desired land is assumed (desired, not necessarily taking place).
Initial average fertilizer use/Km^2	13.79 tonnes (World Bank, 2013).
Organic fertilizer use	Up to 40% of total fertilizer consumption by 2035 under the GE scenario.
Investment in organic fertilizer	It is estimated that an average annual investment of about 300 million baht would be required between 2020 and 2035 to increase the share of organic fertilizer use from 0% to 30% over the same period (approximately $100/ha/year).
Ecological agriculture water use	30% reduction compared to conventional agriculture. (Pimentel, Hepperly, Hanson, Douds, & Seidel, 2005)
Average agriculture land for per capita food production	0.004 km2 per person = 1 acre per person (Bradford, 2013). The area needed for food production is assumed to decrease with the increase in agricultural productivity.
Agricultural productivity	It is assumed that changes in fertilizer use, soil quality, and labour productivity would have a positive -but not immediate- impact on agricultural productivity.
Employment	
Potentially active people (labour force)	60% of total population, calculated on the basis of population cohort between 15 and 59 (Indepth Network, 2013).
Residential people employed in agriculture	45.94% of the population, derived from the fraction of agricultural employment in the Kanchanaburi region (IPSR, 2007)
Initial average income of farmer's household	15,326 Baht (UNDP, 2010)
Average farmers needed/km2	69.86 farmers/km^2 in the No-road and BAU scenarios, derived from initial values of people employed in agriculture and initial area of agricultural land in the Kanchanaburi region (UNDP, 2010). In the green economy scenarios, the adoption of ecological agriculture practices is expected to produce a 30% increase in employed farmers (Herren, Bassi, Zan, & Binns, 2012)
Average household income: road construction/maintenance	Assumed to be 50% higher than initial average income of farmer's households

Workers needed for road construction	11.3 per km of road (CLRC, 2004) (World Bank, 2013).
Road maintenance labour	1 worker for 3 km of road (Donnges, Edmonds, & Johannessen, 2007).
Carbon capture and sequestration	
Average CO_2 absorbed by forests	8,600 tonnes of CO_2 per km^2 of forest.
Price per ton of CO_2	123 Baht, or $4.

3.4. Scenarios

Three main scenarios are simulated and analysed in this study, as presented below.

- A **No-road** scenario, under which the construction of the road is halted. Simulations under this scenario are used as a reference to evaluate projected positive and negative impacts of road construction on the economy, society and environment. The No-road scenario assumes the continuation of historical and present trends.
- A **Road** scenario case that assumes the construction of the road between Kanchanaburi and the Thailand-Myanmar border, but no additional policies implemented to mitigate possible negative impacts on natural capital and ecosystems. Under this scenario, the full impact of road construction is projected on the economy, society and environment, considering the complex relations between land use changes, ecosystem services and socio-economic indicators.
- Two **Green Economy scenarios**, on top of the road scenario, that simulate additional interventions for the protection of natural capital, including investments in ecological agriculture practices to increase yield and reduce soil erosion; water efficiency in agriculture; and reforestation activities. The first scenario is an easier "win", and more likely to occur. Scenario 2 represent an even greater investment and ambition level for sustainable land and land use management:
  - *Green Economy 1 (GE-1)*: Starting from 2019, immediately after the completion of the road, investments are introduced to expand organic agriculture land up to 40% of total agriculture land by 2030. Moreover, reforestation activities are initiated in 2015, making use of degraded agricultural land.
  - *Green economy 2 (GE-2)*: In addition to the policies listed above, land-use planning is introduced in order to meet socio-economic development needs whilst safeguarding the environment. In particular, sustainable urban planning measures are implemented in order to reduce settlement land per capita, thereby optimizing the use of existing urban areas to cope with projected population growth following the construction of the road. Moreover, improved efficiency in agriculture, and higher population density, are assumed to lower the average size of agricultural land available per capita. It is assumed that, as a result of land use planning, per capita urban areas would be reduced from 0.006 km^2 to 0.004 km^2 between 2019 and 2035; and per capita agriculture land declines from 0.004 km^2 to 0.003 km^2 in the same period.

The results of these simulations are presented in the following sections of the report.

4. MAIN RESULTS

In the following sections results are presented for the No Road, Road and Green Economy (GE-1 and GE-2) scenarios. Specific considerations are made for the economic valuation of ecosystem services, employment creation and income generation.

4.1. 'No Road' scenario

The first scenario assumes that the construction of the road is halted, and the simulation projects the continuation of current land-use, environmental and socio-economic trends. In particular, limited employment opportunities would lead to a continuation of current emigration trends, causing a decline in residential population every year. As a result, increasing portions of urban and agricultural land would be abandoned every year, with negative impacts on production. Apart from agriculture land, all other land uses remain largely unchanged under the No-Road scenario.

4.2. 'Road' scenario

The "Road" scenario assumes that 80 km of road are constructed between Kanchanaburi and the Thailand-Myanmar border, without any additional interventions to mitigate possible negative impacts on natural capital. As described in Section 3, this scenario assumes that the route decided for construction cuts across forestland, thereby requiring the clearing of about 10.6 Km² of forests (average estimated across all the possible road construction options included in the InVEST study). Projections show a variety of effects of road construction on the whole socio-economic and environmental system of the concerned area.

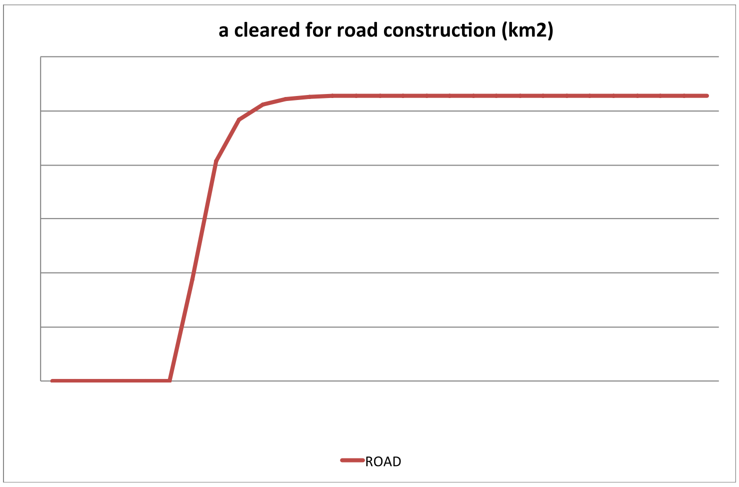

Figure 7 : Area cleared for road construction (km^2)

More specifically, building the highway is expected to increase the economic attractiveness of the area. For example, national and foreign investments could be mobilized for the development of agricultural production for export purposes. In fact, the InVEST analysis and survey show a likely transition to more intensive agriculture from perennial crop cultivation (approximately in 20% of cases). Moreover, the connection with the Dawei port, expected at the end of the Dawei deep sea port project, could further contribute to classify the area as strategic for production and trade-related business.

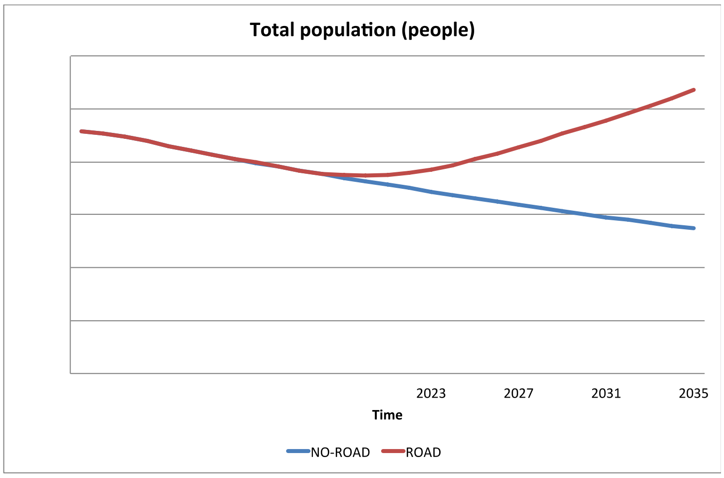

Figure 8 :Total population under No-Road and Road

Another possible effect of road construction is the reversal of current demographic trends (see Figure 8). Under the Road scenario, new employment opportunities are created in the Kanchanaburi area, especially related to road construction and maintenance work, as well as additional workforce needed to sustain the expansion of agricultural production and trade. The residential population would thus be encouraged to remain in the region and exploit new economic opportunities. As a result, the out migration flow is assumed to progressively reduce, and completely stop by 2025. Moreover, enhanced economic development is expected to attract new workers from outside the area. The simulation shows a 7% increase in total population between 2018 (completion of the road) and 2025, going from 686,100 to 734,400 people, and eventually reaching 972,100 people in 2035 (a 41% increase relative to 2007).

The combination of road construction, demographic growth and investments in agricultural production is expected to meaningfully change land use if no dedicated planning is enforced. More specifically, projections show that:

- The total area needed for road construction would amount to 10.56 km^2, and is assumed to be obtained entirely through deforestation.
- Agricultural land would increase from 2,931 km^2 in 2018 to 3,237 km^2 in 2025 and 3,934 km^2 in 2035, corresponding to a 10.4% and a 34.2% increase, respectively (see Figure 9). Under this scenario, total agriculture land in 2035 is expected to be 64% larger than under the No Road scenario. The expansion of agricultural land is assumed to be done entirely at the expenses of forestland, and productivity would be enhanced using chemical fertilizers (with over 20% growth relative to the No-road by 2025).
- The urban area is expected to increase by 13.2% compared to the No Road scenario in 2035, going from 4,749 km^2 to 5,375 km^2. The land used for settlements is assumed to be converted entirely from degraded land, with no impact on forest cover.
- Forestland would be reduced under the road construction scenario with respect to the No road scenario, due to the impact of agricultural land expansion and land clearance for construction works (see Figure 11). In 2025, the forest cover is expected to be 5% smaller compared to the No Road scenario, and 16.6% smaller in 2035, going from 11,230 km^2 in 2013 to 10,360 km^2 in 2025, and 8,952 km^2 in 2035.

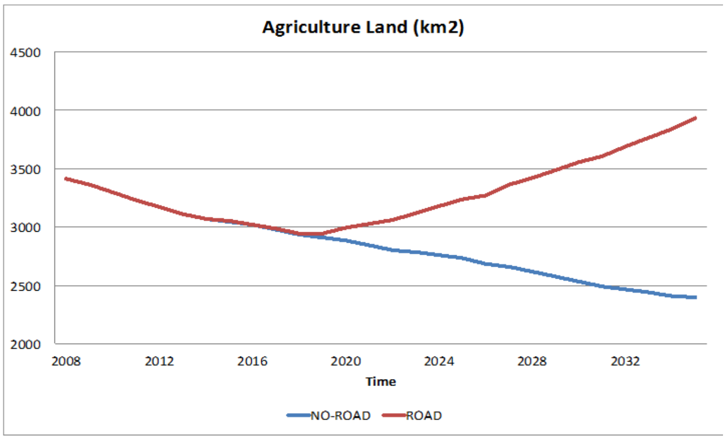

Figure 9 : Agriculture land under No-Road and Road

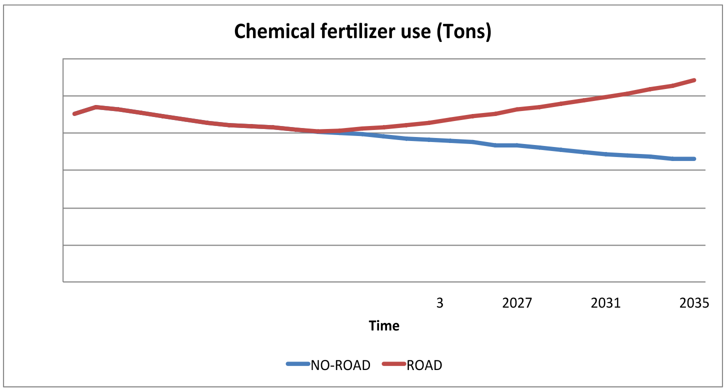

Figure 10 : Chemical fertilizer use under No-Road and Road scenarios

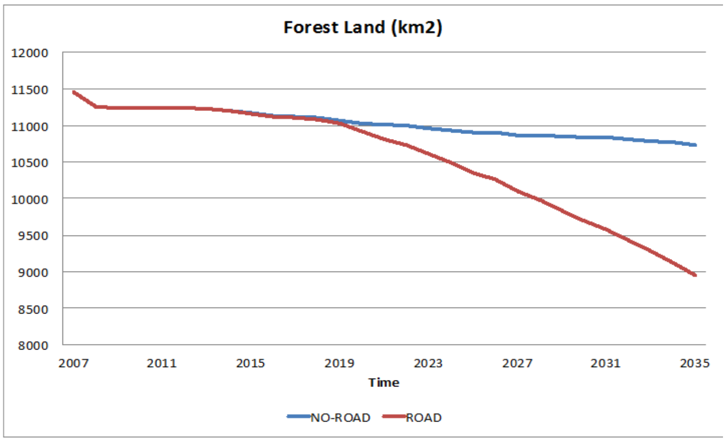

Figure 11: Forest land under No-Road and Road scenarios

The modification of the natural landscape resulting from the construction of the road would increase pressure on natural resources and ecosystem services. In particular, the reduction of forest cover is expected to have a destabilizing impact on the regulation of the hydrological cycle, thereby increasing the occurrence of floods associated with heavy rainfall, eventually removing top soil, increasing river siltation and sedimentation levels, and reducing surface water inflow. On the other hand, water consumption is expected to increase significantly, due to a growing demand for agriculture and residential purposes. As a result, the water balance, calculated as the difference between total water supply and total water demand, is expected to evolve from equilibrium in 2013 to a significant deficit in 2035, with demand exceeding supply by 0.61 km^3 (see Figure 12).

In addition to the impacts on water availability, land use modifications would trigger a number of simultaneous effects on agricultural productivity. On the one hand, the increase in farmers' density is expected to have positive feedback on productivity (e.g., through mechanization and economies of scale) (see Figure 13). On the other hand, however, the environmental impacts produced by deforestation and unsustainable agricultural practices would threaten the sustainability of the sector in the medium to longer-term. More precisely, the increased occurrence of floods and the extensive use of chemical fertilizers are likely to affect crop cultivation and cause soil erosion and degradation (Paarlberg, 2010), with negative impacts on yields.

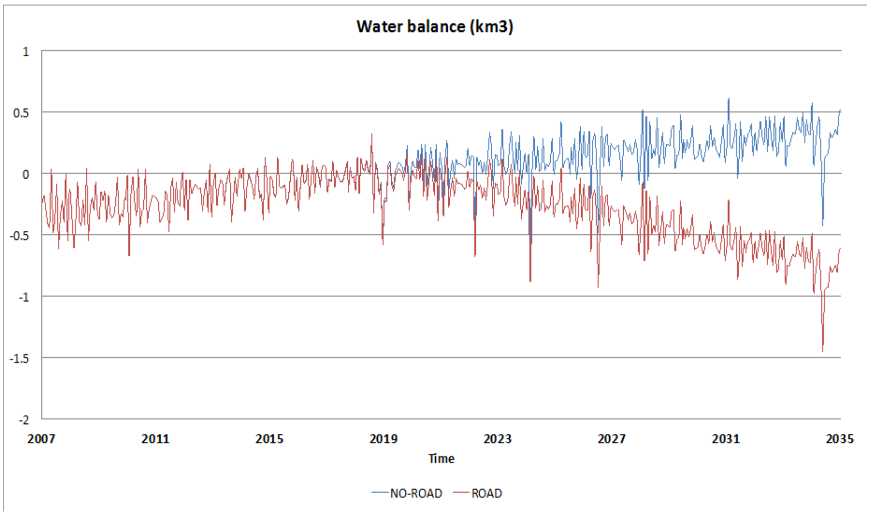

Figure 13 : Water balance (supply minus demand) under No-Road and Road scenarios

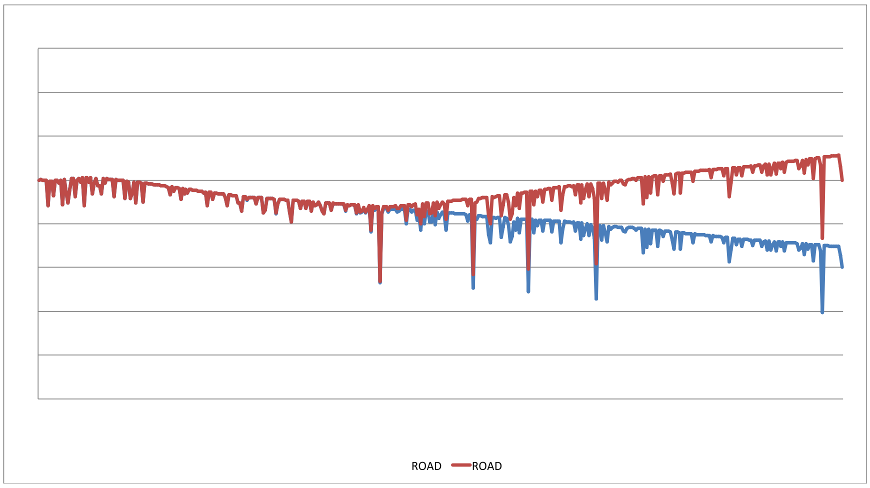

Figure 12: Agricultural productivity under No-Road and Road scenarios

4.3. 'Green economy' scenarios

The construction of the road between Kanchanaburi and the Thailand-Myanmar border is expected to introduce significant changes in the economic, social and environmental dynamics of the area considered. In particular, the improvement of transport infrastructure would generate new economic opportunities, whose impact on development largely depends on the production and consumption patterns emerging across sectors. As presented earlier, the growth in population and resource intensive growth (continuing current trends of land use) would put considerable pressure on the environment, and possibly leading to negative consequences for the well-being of the population in the medium and longer term.

Starting from these considerations, a number of green economy interventions can be identified and implemented in order to mitigate negative impacts of land-use changes, while still accruing the benefits of the road construction project. In particular, investments in ecological agriculture practices and water efficiency in the agriculture sector, and reforestation activities are tested.

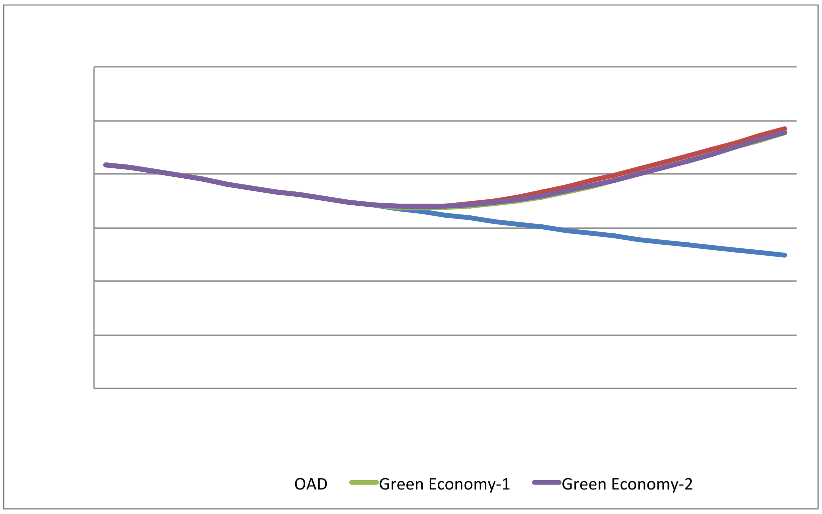

Figure 14: Total population under No-Road, Road and GE scenarios

Hereafter are presented the results of two green economy scenarios (GE-1 and GE-2). The GE-2 scenario simulates the same policies as the GE-1 scenario, but also adds interventions representing a more sustainable land use planning and improved resource efficiency.

The comparison of results between the green economy scenarios and the Road scenario can shed light on alternative economic, social and environmental trends in the region analysed.

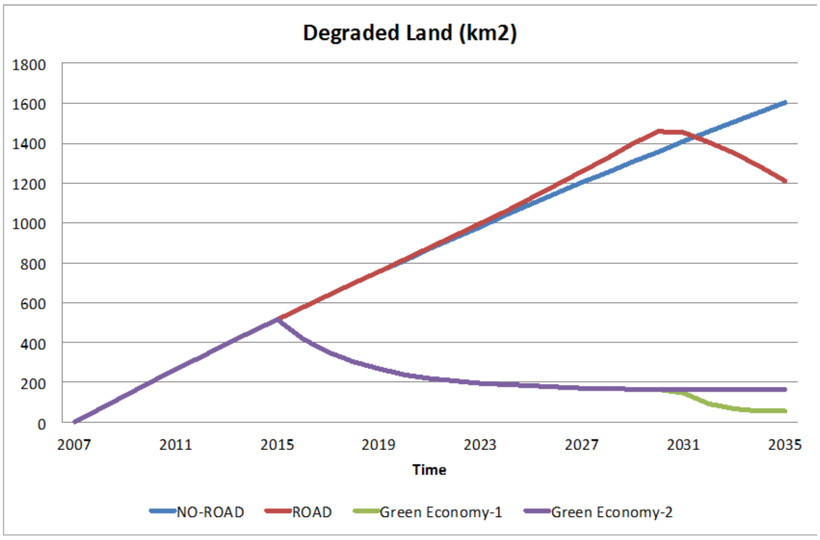

Figure 15: Degraded land under No-Road, Road and GE

Firstly, population growth under both green economy scenarios is nearly equal to the one expected under the Road scenario. As result, GE-1 retains the economic benefits of the road scenario (see Figure 14).

Secondly, it is important to notice that degraded agriculture land is converted for both reforestation and urbanization purposes under the green economy scenarios, while it is entirely used for satisfying urban land needs under the road scenario. Under the road scenario the population grows considerably, and it is assumed that we use land cleared for road construction first and then, if needed, degraded land is used for urban land as needed.

As a result, given the projected need for urban land, in the GE-1 scenario most degraded land is used for reforestation, while part of the land cleared for road construction and some forestland (in the longer term) is converted to urban use. This is a potential side effect of the green economy intervention that is addressed in the GE-2 scenario (see Figure 16). In fact, the improved land planning introduced under the GE-2 scenario would offset the impact of demographic and immigration trends on land use, thereby preventing any additional land clearing and deforestation for settlement purposes.

Synergistically, improved efficiency in the agriculture sector would reduce the expansion of agriculture land (see Figure 17). As a result, total forestland would grow, reaching 10,882 km² in 2035 under GE-1, compared to 11,693 km² under

GE-2 in the same year. In both green economy scenarios, forest land cover in 2035 is projected to be larger than in the Road scenario, and precisely by 21.6% and 30.6%, respectively.

Despite similar demographic growth projections in the GE and Road scenarios, the use of agriculture land is considerably reduced in the former after the introduction of ecological agriculture practices, due to positive impacts on crop yields and soil quality. More specifically, total agriculture land would reach 3,251 km² under GE-1 and 2,863 km² under GE-2 scenario in 2035, compared to 3,934 under the Road scenario, corresponding to a 17.4% and 27.1% decrease, respectively.

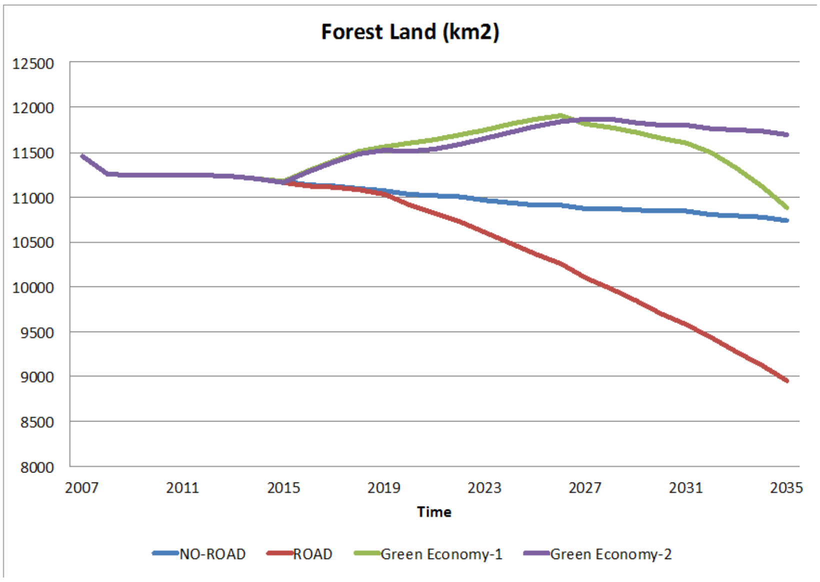

Figure 16: Forest land under No-Road, Road and GE scenarios

Another impact of green agriculture is the reduction of water use in organic farming. Projections show that total agriculture water demand in 2035 would be 29.8% lower in the GE-1 and 38.2% under GE-2 scenarios relative to the Road scenario. In addition to the reduction in agriculture water demand, the incidence of floods on river siltation would be reduced under green economy scenarios, due to the preservation of forestland and its water cycle regulation service. As a result, the water balance would be radically different between green economy and Road scenarios, with a surplus of 0.29km³ (GE-1) and 0.54 km³ (GE-2), compared to a deficit of 0.61 km³ in the Road scenario in the same year (see Figure 18).

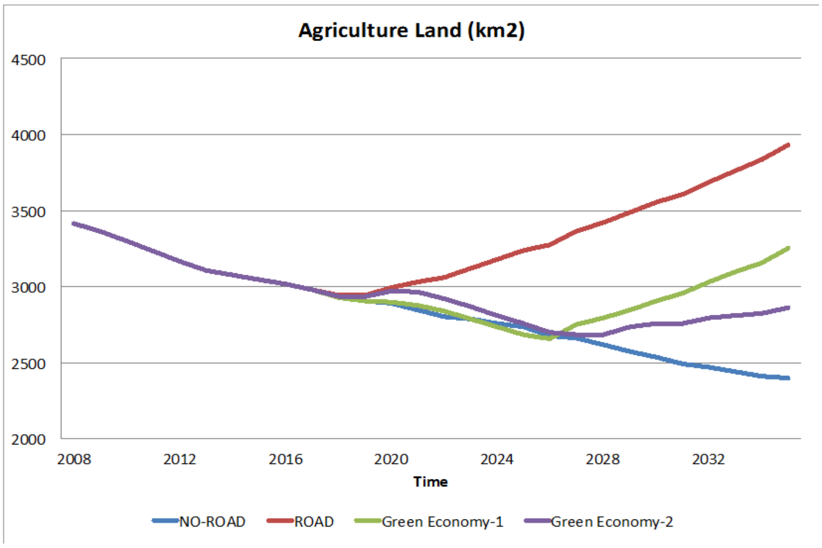

Figure 18: Agriculture land under No-Road, Road and GE scenarios

Concerning socio-economic impacts, ecological agriculture practices generally require more labour force than conventional agriculture. According to studies conducted in developing countries, organic agriculture has the potential to increase jobs by 30% compared to traditional agriculture methods (Herren, Bassi, Zan, & Binns, 2012). Despite this positive impact on employment in the GE case, the total amount of people employed in the sector is projected to be larger under the Road scenario, due to the higher expansion of agricultural land relative to the green economy scenarios.

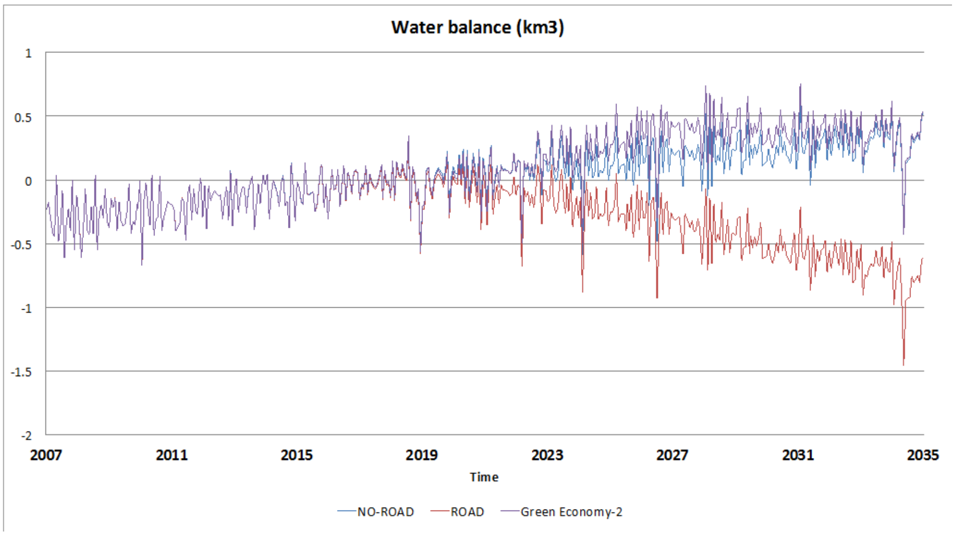

Figure 17: Water balance (supply minus demand) under No-Road, Road and GE scenarios

This also means that income per farmer would be higher in the GE cases. Projections show that 5,387 additional jobs could be created every year between 2020 and 2035 under the Road scenario, compared to 4,207 under GE-1 and 2,354 under GE-2 scenario in the same period (see Figure 19), generating a cumulative additional income of 1.2 billion baht (Road), 967.1 million baht (GE-1) and 541.1 million baht (GE-2), assuming no price premiums for ecological agriculture. With a price premium, per capita income would certainly be higher in the GE cases than in the Road and No-Road scenarios. Further, it is reasonable to assume that improved yield and soil conditions (on average up to 80% higher than in the case of conventional agriculture practices (Pretty, et al., 2006)) are likely to enhance the sustainability of the sector in the long-term, thereby reducing possible future risks of job losses due to land degradation and increased frequency of floods, among others.

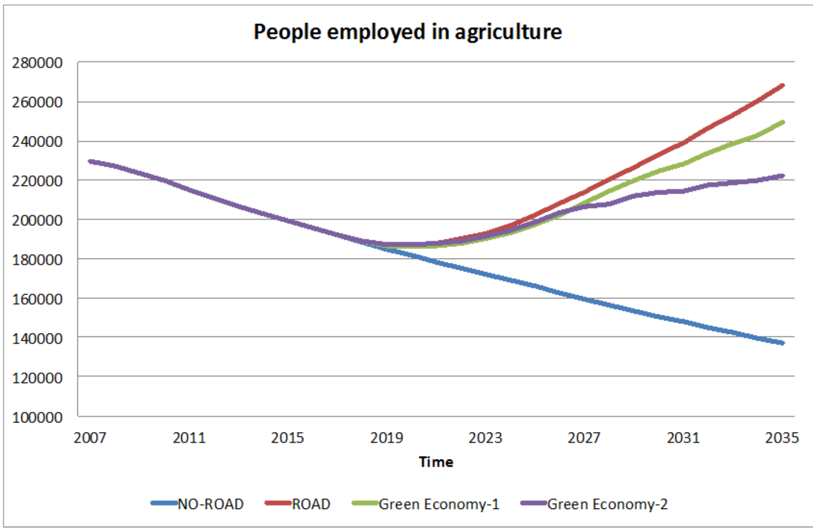

Figure 19: People employed in agriculture under No-Road, Road and GE scenarios

Finally, reforestation activities under green economy scenarios would increase the total amount of CO_2 absorbed by forests, compared to both the Road and No Road scenarios. More specifically, the stock of carbon capture and sequestration would amount to 101.4 million tonnes of CO_2 in the GE-1 scenario and 105.5 million in GE-2 scenario in 2035, compared to 83.33 and 96.63 million tonnes of CO_2 under the Road and No Road scenarios, respectively. Considering an approximate value of 123 Baht per ton of CO_2, the carbon stored in forests could be worth 2.73 billion Baht in the GE scenarios relative to the Road case.

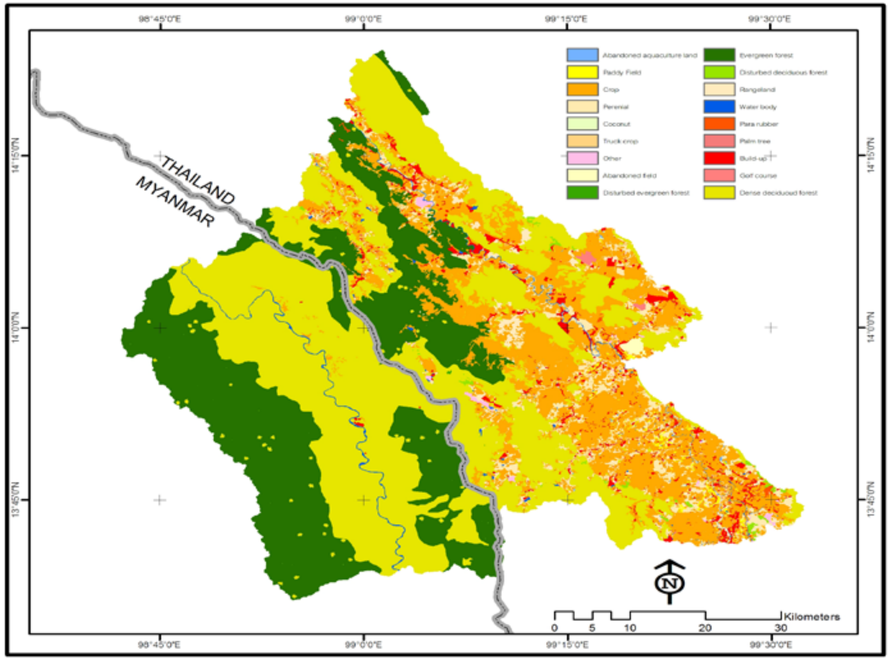

Figure 20: No Road scenario

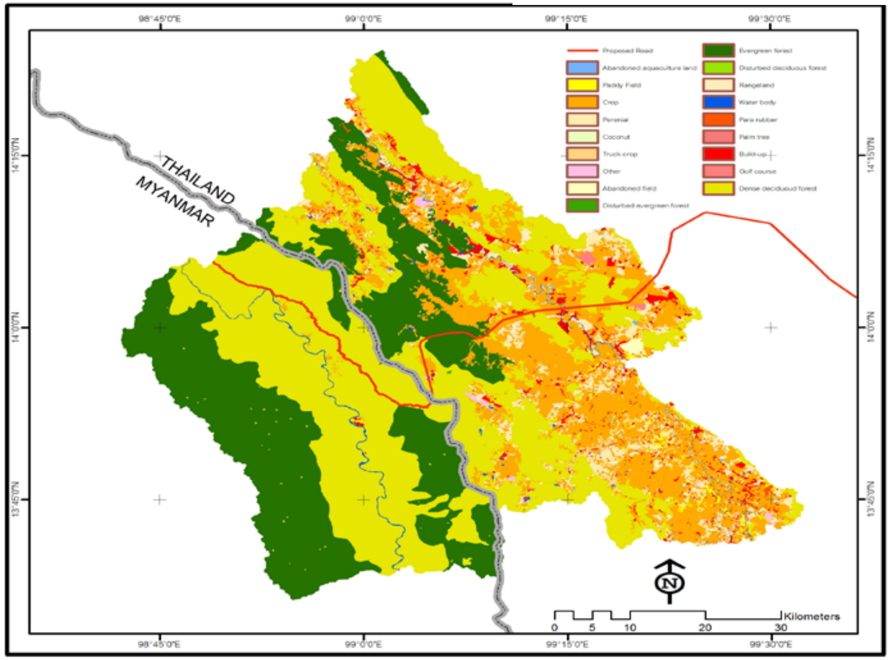

Figure 21: Road scenario (no green economy intervention)

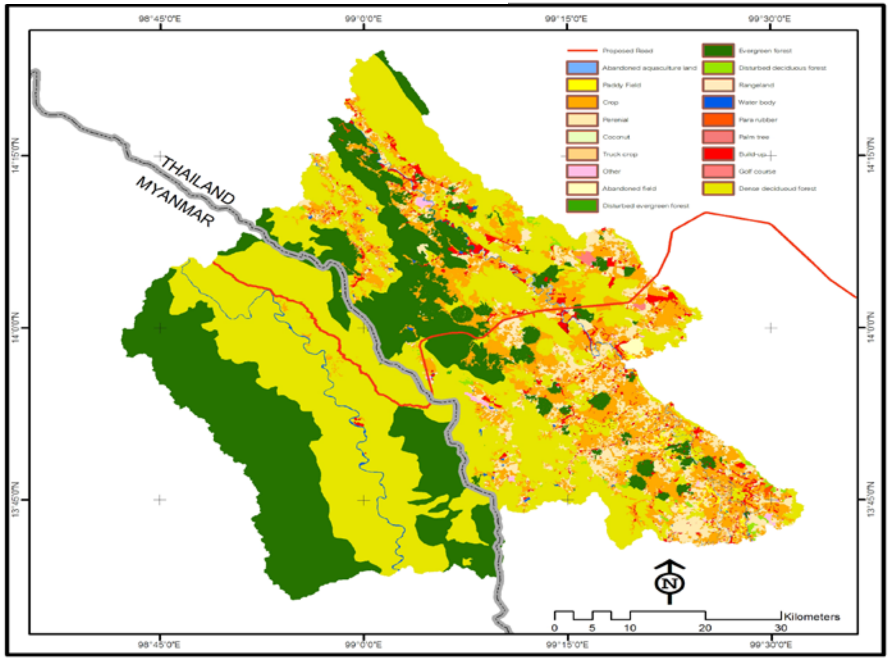

Figure 22: Green Economy Road scenario

As a key conclusion, the scenario development exercise illustrated in the above figures proves that the model works given the additional coverage of evergreen forest in Figure 22 the Green Economy Road scenario as compared to the scenarios of no further road development, or road development with no supporting sustainable land use management policies.

The green economy scenario shows what *might* be possible under one set of interventions – note that the model could be used again and again to run other types of interventions. For example, the dispersed coverage of evergreen forest observed in the Green Economy Road scenario may not yield the biggest conservation gain (again see Figure 22 above). A different intervention could be modelled to achieve concentration of that replanting, or dispersing it linearly along the road. As such, the analysis above should be treated as validation of the prototype model developed rather than a recommendation for green economy policy interventions in extending the Southern Economic Corridor through Bangkok to Dawei.

A model with environmental, social and economic indicators all included allows for a more realistic baseline from which to plan for both economic development and conservation and other environmental policy interventions. It may indicate where efficiencies for economic development can be gained from managing natural capital proactively in land use change, through for example, managing water risks for human settlements, or agricultural and industrial activities. From a conservation practitioner point of view, the model can be used to identify successful conservation outcomes (i.e. a pure focus on ecosystem integrity) which then can be 'translated' into economic and social benefits from those interventions. Furthermore, recognising that viable conservation will in some cases impose a net cost on public finance (perhaps with conservation benefits too far off in the future or distributed too thinly across human populations to count), a model such as this prototype on transport can help us to identify policy interventions that offset these costs. Information such as this allows WWF and their partners to discuss the indicators, values and impacts of conservation in terms of socioeconomic outcomes.

4.4. Economic valuation of natural capital

In the previous section, potential impacts of the highway construction project on DTL's natural capital, economic and social development were projected and analysed under different scenarios, including the implementation of targeted green economy interventions aimed at mitigating the negative impacts of land use change on ecosystems. Based on the outcome of the analysis, this section seeks to assign an economic value to natural capital and ecosystem services, in order to better define the relation existing between the economy and the environment, and to show the importance of the full incorporation of natural capital in the analysis underlying decisions on budget allocation and project implementation, or, more generally, in the decision and policymaking process.

The main results of this preliminary analysis follow. The assumptions used are presented in Table 2, and specific numerical results are presented in Table 3 (value of natural resource stocks) and Table 4 (annual change in the value of natural resource stocks).

Table 2: Assumptions and references used for the valuation of natural capital and ecosystem services

Variable	Unit	Value	Reference
Value of forests	Baht/km^2	2.7 million Baht (or US$ 90,000)	Estimated based on the weighted average potential profit from land use, including timber, palm oil or crop production. Palm oil and crop yield use local estimates, timber production uses global averages
Value of carbon sequestration	Baht/TCO$_2$	123 Baht (or US$ 4)	Estimated based on extensive review of current carbon prices in different markets. The low-value scenario was simulated in this study. However, higher values (up to 450 Baht/TCO$_2$) could be reasonably assumed and simulated (Venter, et al., 2011)
Value of biodiversity	Baht/km^2	81,000 Baht (or US$ 2,700)	The range of values found in the literature is as low as US$4.6 per hectare per year (Pierce & Pierce, 2001) to US$9,177 per hectare for pharmaceutically rich areas in Ecuador (Rausser & Small, 1998)
Value of agriculture land	Baht/km^2	4.2 million Baht (or US$ 140,000)	Calibrated using historical data on crop yield and production at the aggregate national level (FAO, 2011). Crop values are estimated based on international market prices.

Forest

The construction of the highway and the expected increase in population and expansion of agricultural land would lead to deforestation in the DTL. On the one hand, deforestation contributes to the depletion of natural capital and the loss of ecosystem services that are fundamental for socio-economic development. On the other hand, economic benefits can be derived from the conversion of forestland into agriculture land, as well as the extraction of forest timber products. As a result, a possible way to estimate the economic value of forests consists in the calculation of the potential profit that could be derived from deforestation activities, considering the value of timber products and possible alternative land uses after deforestation. In this study, an estimation of the average value of forests was made based on the weighted average of potential profits of different land uses, including timber production, plantations and crop production. The approximate value per Km^2 of forestland is assumed to be 2.7 million Baht.

Carbon

A vital function of forests is the absorption of carbon dioxide from the atmosphere through photosynthesis, and its storage in the form of organic matter and root biomass. As a result, the forest cover directly influences the amount of carbon captured and stored every year. The absorption of CO_2 emissions is essential to reduce the level of greenhouse gases in the atmosphere, thereby mitigating climate change and its harmful effects. Moreover, the organic matter produced by forest trees from carbon increases nutrient levels in soil, improving water retention and reducing groundwater contamination. The economic value of carbon capture and storage can be estimated on the basis of current and projected trends in the carbon emissions market. For the purpose of this study, an average price of 123 Baht (or US$ 4) per ton of CO_2 was used to calculate the impact of carbon prices on natural capital in the DTL.

Biodiversity

The extraordinary variety of plants, animal species and habitats in DTL's forests means that the level of biodiversity is particularly high in the area interested by the construction of the highway. In particular, a critically endangered species of tiger finds in this area its natural habitat (WWF, 2013c). The projected expansion of agricultural production in the area, resulting from demographic growth and increased economic attractiveness following the construction of the highway, is likely to cause significant changes in land-use distribution, thereby negatively impacting habitat quality and biodiversity. In order to quantify the impact of land-use changes on biodiversity under different scenarios, an economic value can be estimated and assigned to each km2 of forestland. In this study, an average value of 81,000 Baht per km2 of forestland was used based on tourism case studies available (Pierce & Pierce, 2001) (Rausser & Small, 1998) for specific habitats and species found in the DTL. It is worth noting that this value is likely to be relatively low-value use of biodiversity when compared to other uses like non-timber forest production, for example.

Agriculture land productivity

The development of the agriculture sector is one of the projected socio-economic impacts of road construction in the area of study. Increased agricultural production is likely to generate additional profits, employment and income. However, unsustainable and uncontrolled agricultural practices might contribute to ecosystem degradation and loss of natural capital. In particular, the intensive use of chemical fertilizers and pesticides would reduce soil quality and crop yields in the medium and longer term, possibly leading to further deforestation. On the other hand, the introduction of ecological agriculture practices through investments in organic fertilizers would increase productivity and generate additional jobs, at the same preserving the environment and limiting deforestation. In particular, crop yield under organic farming is assumed to be 30% higher than under conventional agriculture (Pretty, et al., 2006). Based on these considerations, crop values and production trends at the national level (FAO, 2011) were used to estimate an approximate value of agriculture land under different scenarios, approximating 4.2 million Baht per Km^2.

Water

The abundant forest cover in the DTL provides essential ecosystem services and contributes to the availability of freshwater. In particular, forests play a central role in regulating overland flow, maintaining groundwater and preventing floods. Intensive deforestation, if not compensated with forest planting policies, would weaken the capacity of forests to provide these ecosystem services, which would need to be replaced. As an example, the lack of surface water resources would require public investments in infrastructure, e.g. for the construction of reservoirs, pipelines and pumping stations. Negative impacts on water resources might also derive from unsustainable agricultural practices. The increase in the use of chemical fertilizers might lead to soil erosion, infiltration and consequent groundwater pollution.

Table 3: Total value of natural capital and ecosystem services under different scenarios (Baht)

	Scenarios	2015	2025	2035
Total forest natural capital	Road	30.1 B	28 B	24.2 B
	Green Economy-1	30.1 B	32 B	29.38 B
	Green Economy-2	30.1 B	31.8 B	31.6 B
Total value of carbon sequestration	Road	12.29 B	11.55 B	10.25 B
	Green Economy-1	12,29 B	13,06 B	12,48 B
	Green Economy-2	12.29 B	12.99 B	12.98 B
Biodiversity natural capital	Road	903.7 M	839.2 M	725.1 M
	Green Economy-1	903.7	961.48	881.42
	Green Economy-2	903.7 M	954.6 M	947.1 M
Total value of agriculture land	Road	13.8 B	13.8 B	14.8 B
	Green Economy-1	13.8 B	13.8 B	14 B
	Green Economy-2	13.8 B	13.8 B	13.8 B

Table 4: Annual value of natural capital and ecosystem services under different scenarios (Baht)

	Scenarios	2015	2025	2035
Annual forest natural capital	Road	-114.1 M	-236.1 M	-429.5 M
	Green Economy-1	357,29 M	162,25 M	-593,82 M
	Green Economy-2	352.3 M	165.8 M	-24 M
Annual value of carbon sequestration	Road	-38.3 M	-90.1 M	-147 M
	Green Economy-1	145,36 M	63,57 M	-95,25 M
	Green Economy-2	144.4 M	65 M	-1 M
Annual Biodiversity natural capital	Road	-3.4 M	-7.9 M	0
	Green Economy-1	10,72 M	4,867 M	-17,81 M
	Green Economy-2	10.6 M	5 M	1 M
Annual value of agriculture land	Road	0	6.9 M	33.8 M
	Green Economy-1	0	-11,28 M	26,39 M
	Green Economy-2	0	-11.6 M	4.6 M

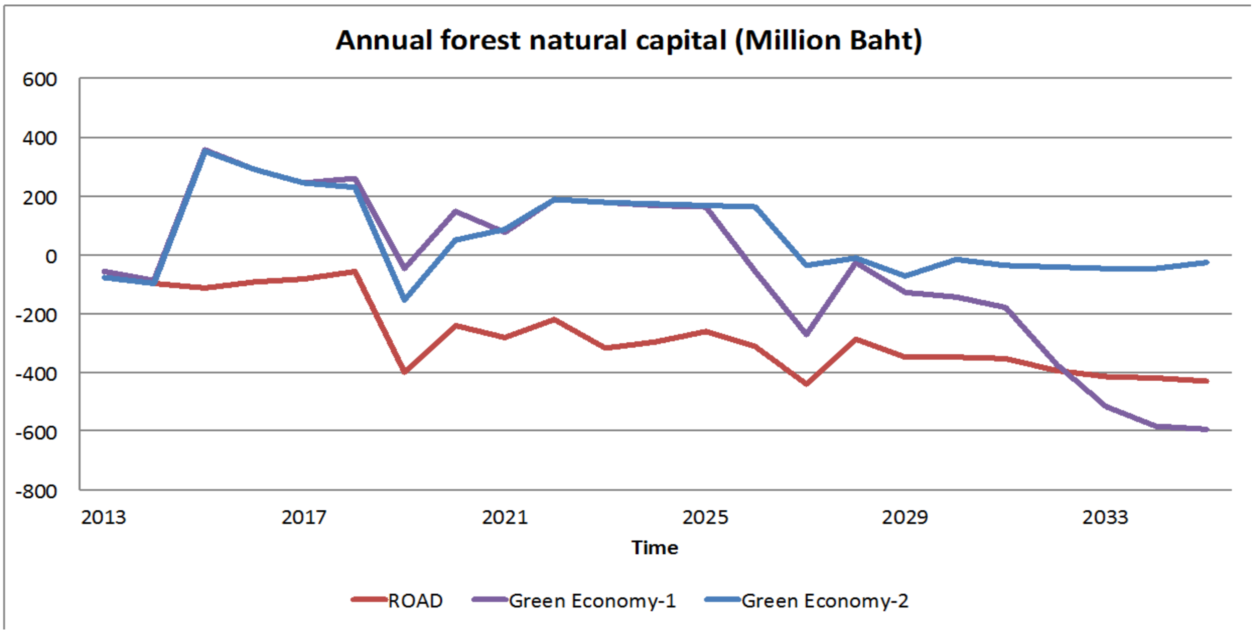

Figure 22: Annual change (flow) of forest natural capital under Road and GE scenarios

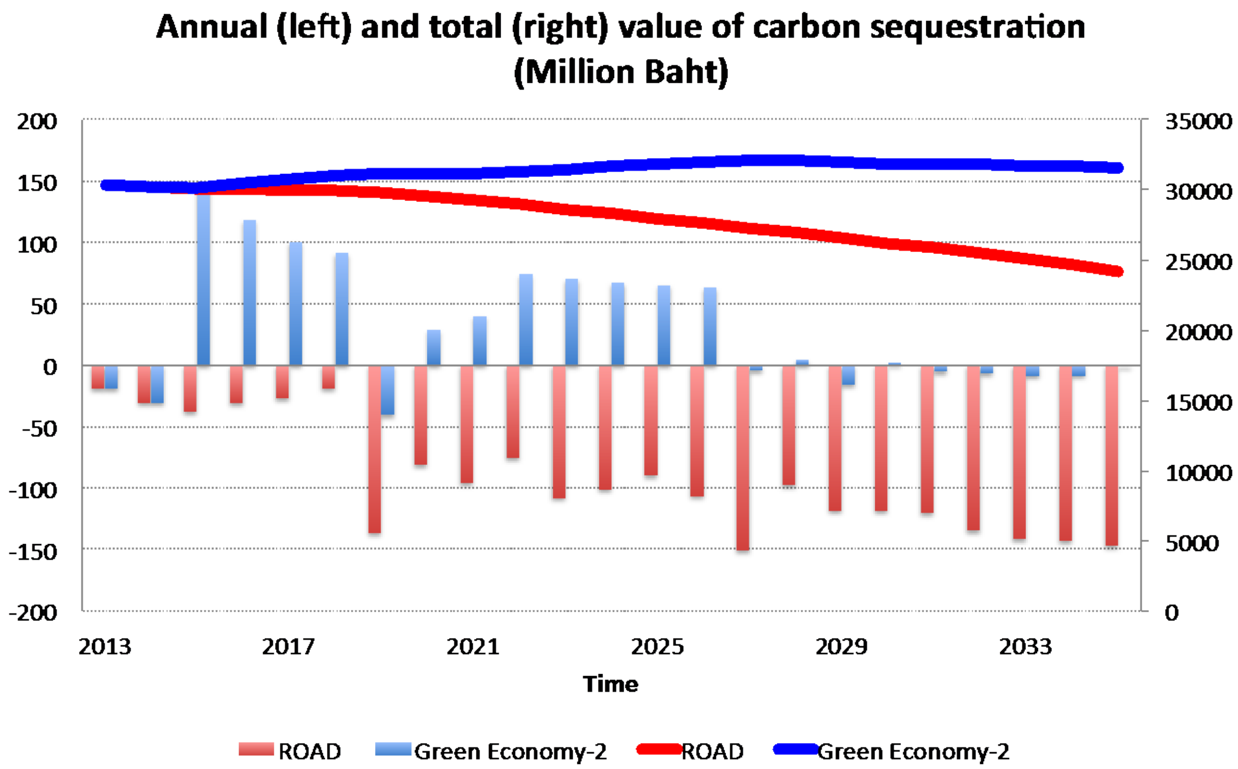

Figure 23: Annual (left, bars) and total annual value (real, inflation adjusted) (right, lines) of carbon sequestration under Road and GE scenarios

5. POLICY CONSIDERATIONS

The construction of the highway in the Kanchanaburi region is expected to produce benefits for the local economy. Indeed, the improvement of transport infrastructure would certainly create opportunities for the commercialization of local products, possibly attracting investments for the growth of trade within the region, and import-export activities with the neighbouring Myanmar. The local population could benefit from economic growth, in particular due to the creation of new employment opportunities, and potential improvements in household income and livelihoods.

However, despite the establishment of modern infrastructure being an essential step towards the achievement of key development objectives, a number of considerations -partially addressed in this study- should be taken into account when estimating the impacts of road construction in the Kanchanaburi region and the DTL. More specifically, the identification of environmental issues that could reduce and possibly offset some of the benefits of infrastructure development is key. This can be done using a systemic approach, which considers the main properties of real systems, including the presence of feedback loops and delays, potentially leading to the emergence of side effects in the medium and longer term. Key aspects to be considered include:

- Firstly, short, medium and longer-term impacts have to be clearly identified. As it was shown, short-term positive impacts (e.g. on livelihoods and economic attractiveness) might be offset by medium and long-term indirect and induces trends, including negative consequences of environmental degradation. The introduction of targeted green economy interventions for the protection of natural capital and ecosystem services is expected to alleviate environmental pressures, creating the enabling conditions for sustainable and inclusive development. A more detailed study could show the cost of replacing ecosystem services, to objectively compare advantages and disadvantages of various scenarios.
- Secondly, the distribution of costs and benefits across different actors should be clearly assessed. In particular, a sudden economic expansion, when coupled with unregulated land exploitation, might lead to speculations that would be made at the expenses of the environment and the well being of the local population, for the exclusive benefit of a limited number of actors. Green economy interventions, such as the establishment of protected forest areas, the adoption of sustainable forest management principles and practices, need to support a fair and inclusive development.
- Thirdly, an integrated, cross-sectoral approach should be used for the evaluation of costs and benefits, as well as broader advantages and disadvantages, of project implementation. Synergies can be created a cross sectors. While the growth of population and the expansion of agriculture are likely to increase pressure on natural resources (e.g., forest), the adoption of ecological agriculture practices can curb the needs for agriculture land.

Green economy interventions were simulated in this study for two key sectors that hold considerable potential in the local context: agriculture and forest. The policies analysed should be planned and implemented taking into careful consideration a number of issues that are key for success, including:

- The policy instruments available to support the agriculture sector are many and varied. With information on the investment required, and the expected benefits, a policy package can be designed. In particular, the use of a combination of instruments is advised, including incentives to lower the burden on households (e.g., subsidies for the conversion to ecological farming practices), and regulations (e.g. on chemical fertilizer use) to ensure that the desired goals are reached. Moreover, different economic actors should be addressed separately, with dedicated policy interventions, to ensure that cost allocation is fair and that the distribution of benefits is inclusive. Finally, given that organic agriculture is expected to produce gradually higher returns than conventional agriculture practices, incentives and other supportive measured should be phased out over time, to allow the sector to invest in innovation and become more competitive at the national and regional level.
- Reforestation activities should be conducted in the framework of public transparent land-use plans, possibly created on the basis of broad stakeholder consultations (e.g. forest communities, private entities, national and international research institutes) in order to maximize benefits for biodiversity and ecosystems, and avoid possible negative impacts on the livelihoods of local communities. In particular, the historic and cultural value of forests should be taken into careful consideration throughout the policy formulation and implementation process.
- Institutional cooperation should be enhanced to facilitate the effective implementation of green economy policies. Coordination between government departments and local authorities is a precondition to ensure the achievement of expected goals.

- Skills and technology transfer programs should complement policy implementation and be carried out in order to create the enabling conditions for the green economy transition in the sectors analysed. In particular, innovative technologies and agriculture practices should be adapted to local market conditions, and adequate training should be provided.

6. CONCLUSIONS

A lack of economic evidence for the role that sustainable ecosystems/resource use plays in economic development means the value of maintaining natural capital is not always obvious outside the conservation community. Assessments of potential impacts from regional transport infrastructure projects tend to focus on the development benefits measured in terms of reduced logistics costs, jobs, revenue and increases in standards of living as measured by household income (OCED, 2002; ADBI 2009). Yet, transport and other infrastructure profoundly influence the integrity of natural systems on which they impact, as well as patterns of trade and development. As such, the economic opportunity from transport, urban, ICT, etc. infrastructure must be balanced against long-term need for natural systems vital to economic and physical resilience. Without this, the economies these corridors drive cannot be sustainable in the long-term because of the high likelihood of loss of critical benefits that nature provides.

Given that environmental and social externalities are typically communicated in 'soft' numbers – carbon emissions for example – decision-makers are missing information on the direct and indirect contribution of biodiversity and ecosystem services in the economy and to human wellbeing**.** This study on ***Green Economy Modelling of Ecosystem Services in the Dawna Tenasserim Landscape (DTL) along the 'Road to Dawei'*** was conceived as a pilot project, aiming at designing an integrated framework to inform and support land use planning support in this context. Four different scenarios were simulated to anticipate possible impacts on economic, social and environmental indicators and impacts for the construction of a highway connecting Bangkok to Dawei, in the framework of the Dawei Deep-sea Port Project. Simulation results show that a conventional approach to road construction is likely to have positive economic impacts in the region, but also negative consequences for the integrity of the ecosystem. Further, results indicate that green economy interventions would mitigate environmental risks by creating synergies across sectors, systemically.

As a key conclusion, this scenario development exercise in the current study validates the prototype model. The results are preliminary and more specific and consistent data are needed on several of the variables analysed. Nevertheless, the study demonstrates the possible use of an integrated approach to evaluate the broader impacts of infrastructure development in the DTL region and shows there is value in exploring the use of a systemic model that incorporate existing knowledge across sectors and disciplines to inform decision making.

The same approach and information could be easily further customized to analyse a variety of infrastructure projects, making use of the value created by the innovation that this pilot study presents: the simultaneous use of InVEST, System Thinking and System Dynamics. Following an approach where stakeholders would validate the model after contributing insights to making the final structure, WWF sees strong potential this integrated approach because:

- A model with environmental, social and economic indicators all included allows for a more realistic baseline from which to plan for conservation and other environmental policy interventions.
- Desired conservation outcomes could be modelled as economic and social benefits. And where viable conservation imposes costs on economic and social development goals, an integrated modelling approach can help identify policy interventions that offset these costs.
- Integrated modelling can be used as assessment tools that incorporate different measures or variables from socioeconomic to pure ecosystem integrity considerations. Such integrated models could be Conservation Impact Indicator trackers or to highlight ecological boundaries or thresholds crucial for resilience in development planning.

In summary, the current study identifies an opportunity for integrated modelling that has been little explored to date. Greater policy coherency is thought to reap efficiency gains. But economic development and land use planning, as well as conservation and environmental policy development tend to be analysed and implemented separately. Part of the reason may be that while many different tools exist as supports to decision-making in these domains, e.g. Geographic Information Systems (GIS), Marxan, they are rarely combined. Moving forward, WWF aims to strengthen a community and method for integrated use of existing tools to make explicit links between ecosystem services and socioeconomic indicators in economic and land use planning.

Table 5: Summary results of the analysis for Road, No-Road and Green Economy (GE) Scenarios

Category	Unit	Scenario	2020	2025	2030	2035
Forest land	Km^2	NO-ROAD	11,032	10,906	10,842	10,732
		ROAD	10,915	10,360	9,704	8,952
		GE-1	11,598	11870	11658	10882
		GE-2	11,511	11,785	11,801	11,693
Agriculture land	Km^2	NO-ROAD	2,888	2,734	2,535	2,399
		ROAD	2,993	3,237	3,556	3,934
		GE-1	2897	2684	2907	3251
		GE-2	2,972	2,755	2,756	2,867
Urban land	Km^2	NO-ROAD	4,749	4,749	4,749	4,749
		ROAD	4,749	4,749	4,758	5,375
		GE-1	4749	4749	4749	5289
		GE-2	4,749	4,749	4,749	4,749
Total population	Person	NO-ROAD	659,837	602,256	546,847	497,663
		ROAD	678,970	734,405	845,189	972,081
		GE-1 and GE-2	678,313	721,488	824,690	957,876
Impact of ecological practices on productivity		NO-ROAD	1	1	1	1
		ROAD	1	1	1	1
		GE-1 and GE-2	1.001	1.451	1.67	1.667
Water balance	Km^3	NO-ROAD	0.104	0.113	0.142	0.525
		ROAD	0.031	-0.249	-0.597	-0.61
		GE-1	0,1235	0,0743	0,0677	0,2221
		GE-2	0.071	0.272	0.305	0.52
Employment in agriculture	Person	NO-ROAD	181,893	166,020	150,746	137,188
		ROAD	187,168	202,449	232,988	267,968
		GE-1	186306	197729	224576	249413
		GE-2	186,987	198,888	214,051	222,602
Annual Household Income (Agriculture + Road Construction and Maintenance)	Billion Baht	NO-ROAD	3	2.9	2.7	2.5
		ROAD	3.2	3.5	3.8	4.2
		GE-1	3.1	3.2	3.4	3.8
		GE-2	3.1	3.2	3.3	3.4
Carbon captured by forests	Million TCO_2	NO-ROAD	98.88	97.93	97.45	96.63
		ROAD	98.08	93.91	88.97	83.33
		GE-1	103,76	106,17	104,88	101,47
		GE-2	103.18	105.62	106.05	105.54
Total economic value of carbon captured	Baht	NO-ROAD	12.16	12.05	11.99	11.88
		ROAD	12.06	11.55	10.94	10.25
		GE-1	12,76	13,06	12,9	12,48
		GE-2	12.69	12.99	13.04	12.98
Biodiversity natural capital	Baht	NO-ROAD	893.60 M	883.34 M	878.19 M	869.29 M
		ROAD	884.09 M	839.19 M	785.98 M	725.13 M
		GE-1	939.47 M	961.48 M	944.27 M	881.42 M
		GE-2	932.40 M	954.61 M	955.90 M	947.11 M
Total value of agriculture land	Baht	NO-ROAD	13.79 B	13.78 B	13.71 B	13.66 B
		ROAD	13.79 B	13.82 B	13.92 B	14.08 B
		GE-1	13.79 B	13.77 B	13.84 B	13.99 B
		GE-2	13.79 B	13.76 B	13.77 B	13.82 B
Total forest natural capital	Baht	NO-ROAD	29.79 B	29.44 B	29.27 B	28.98 B
		ROAD	29.47 B	27.97 B	26.20 B	24.17 B
		GE-1	31.32 B	32.05 B	31.48 B	29.38 B
		GE-2	31.08 B	31.82 B	878.19 M	31.57 B

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Technical Annex

The use of System Thinking, coupled with indicators, causal diagrams and scenarios, is proposed to enable the analysis of future trends emerging from scenarios of action and inaction, collaboration and individual action, assessed across sectors (social, economic and environmental) and actors (e.g., households, private sector and the government), within and across countries. The approach proposed therefore supports integration and participation across and within national stakeholders (e.g., ministries) as well as regionally, as a platform for cross-boundary exchanges.

More specifically, the tools proposed support the identification and analysis of feedbacks, delays and non-linearity existing across sectors and actors. Much effort over the last few years has been devoted to applying these concepts to natural capital, and more specifically climate change impacts. The organizations most active in this field so far have been WWF (primarily through their Natural Capital Project, as well as REDD+ and green economy initiatives), UNEP (through their green economy work), as well as selected governments (of relevance to this project are the cases of Indonesia and Malaysia for national strategies, as well as Thailand and Vietnam for fossil fuel subsidy removal).

The methodology proposed is bottom-up, stimulates conversations and exchanges in workshop and multilateral dialogues. Facilitation is provided by the project team, but the process of identification of indicators, creation of systemic maps of the problem/opportunity and analysis of scenarios is entirely led by the participants. This ensures empowerment and ownership and facilitates open exchanges.

Simulation models can be utilized to effectively support policy formulation and assessment (identifying policy options that will have the desired impact on the system and the right degree of impact) and evaluation (simulating selected intervention options). The simulation models are most commonly used when the analysis is done ex ante, or before the actual implementation of the interventions.

- *Ex-ante* modelling can generate "what if" projections of the expected (and unexpected) impacts of proposed policy options on a variety of key indicators across sectors. In addition, well-designed models, which merge economic and biophysical variables and sectors, can help with the cost-benefit analysis and the prioritization of policy options. The use of structural models that explicitly link policy interventions with their impacts can generate effective projections of how a certain target could be reached and when.

On the other hand, an ex post analysis is useful to monitor trends and analyse why projections may differ from reality in the months and years after policy implementation.

- *Ex-post* modelling can support impact evaluation by improving the understanding of the relations between the key variables in the system and by comparing the projected performance with the initial conditions and historical data. Improvements to the model and updated projections allow decision-makers to refine the targets and objectives, as well as to build on synergies and positive spillovers across sectors.

Through the use of the approach proposed, which has been successfully applied by the project team in over 20 countries, the impact of environmental policy will take into account the full benefits that can be accrued by conserving natural capital (as stocks, flows and provision of ecosystem goods and services) on social, economic and environmental indicators. Only through a multi-stakeholder approach, where various skills and interests are represented, the so-called externalities can be internalized, giving voice to all parties in the decision making process.

The development of a System Dynamic model, including conceptualization, customization and validation, proceeds through a variety of tasks, and the generic steps are presented below:

1. *Identification of key issues and opportunities:* As every model application is unique, the issues to be analysed have to be carefully demarcated and agreed upon. A multi-stakeholder process is often adopted to obtain the widest possible stakeholder views.
2. *Data collection and consistency check:* This is a time-consuming task and, besides data mining, cross-sectoral data consistency checks are an essential step.
3. *Causal mapping and identification of feedback loops:* This step constitutes creating causal loop diagrams (CLDs) as described previously.
4. *Creation of customized mathematical models:* This step is a sequence of iterations involving the key stakeholders. It comprises translating CLDs into mathematical models with numerical inputs and equations. At this stage, the model is built on social, economic, and environmental sectors. In practice it integrates the best sectoral knowledge in a

single model framework. This framework represents the full incorporation of the economic and bio-physical variables that captures (a) feedbacks within and across sectors, which is aimed at identify synergies and potential bottlenecks (unexpected side effects); (b) the time delays, whereby policies and investment allocations may lead to a "worse before better" situation; (c) the non-linearity, leading to the identification of potential thresholds and tipping points.

5. *Validation and analysis*: Variables and equations have to be validated to ensure that all experts feel comfortable with the model's overall structure and that it reflects the reality observed. This is primarily done by simulating the base case and testing the outputs of the simulations against historical data on a multitude of socio-economic and environmental indicators. Decision-makers' confidence that the causal relations in the model are well established emerges from the model's ability to replicate historical data. Where necessary, the model can be calibrated to obtain a consistent and reliable baseline simulation – i.e., the business-as-usual (BAU) case.
6. *Simulation of alternative scenarios*: Once the BAU is confirmed, scenarios can be simulated to test the impacts of alternative policy options, which were identified in Step 1.

As an example, the equations included in the Land Use module, one of the six included in the model, are presented below in alphabetical order.

- *Additional Area Needed For Road Construction Factor= 3*
- *Units: Dmnl*

- *Agriculture Land= INTEG (Deforestation-Land Degradation, 3283)*
- *Units: Km2*

- *Agriculture Land Differential=Agriculture Land-Initial Agriculture Land*
- *Units: Km2*

- *Area Cleared For Road Construction= INTEG (Road Land Clearing-Cleared To Urban Land Conversion,0)*
- *Units: Km2*

- *Attractiveness To Invest In Agricultural Export Products= Delay N(Agricultural Productivity 0to1*Effect Of Road On Attractiveness, 6, 1, 3)*
- *Units: Dmnl*

- *Cleared To Urban Land Conversion=MIN(MAX(0, Gap Between Desired Urban Land And Actual Urban Land/Construction Delay-Degraded To Urban Land Conversion),Area Cleared For Road Construction/Construction Delay *Share Of Area Cleared For Road Construction Converted To Urban Land)*
- *Units: Km2/Year*

- *Construction Delay= 1*
- *Units: Year*

- *Deforestation=MAX(0 , Effective Gap Between Desired Agriculture Land And Actual Agriculture Land/Time To Deforest)*
- *Units: Km2/Year*

- *Degraded Land= INTEG (Land Degradation-Degraded To Urban Land Conversion-Reforestation,1)*
- *Units: Km2*

- *Degraded Land Differential= Degraded Land-Initial Degraded Land*
- *Units: Km2*

- *Degraded To Urban Land Conversion= MAX(0, (MIN(Degraded Land/Construction Delay-Reforestation, Gap Between Desired Urban Land And Actual Urban Land/Construction Delay)))*
- *Units: Km2/Year*

- *Desired Agricultural Land For Export=Agriculture Land*Effect Of Investment On Deforestation*
- *Units: Km2*

- *Desired Agricultural Land For Local Food=Total Population*Km2 Per Person For Food/(Agricultural Productivity 0to1)*
- *Units: Km2*

- *Desired Urban Land= Total Population*Urban Area Per Person*
- *Units: Km2*

- *Effect Of Investment On Deforestation= WITH LOOKUP (Attractiveness To Invest In Agricultural Export Products,([(0,0)-(4,0.1)],(1,0),(1.5,0.04),(2.5,0.075),(3.5,0.095),(4,0.1)))*
- *Units: Dmnl*

- *Effect Of Road On Attractivness= WITH LOOKUP (Road,([(0,0)-(80,4)],(0,1),(20,1.25),(40,2.5),(60,3.75),(80,4)))*
- *Units: Dmnl*

- *Effective Gap Between Desired Agriculture Land And Actual Agriculture Land= Delay N(Potential Gap Between Desired Agriculture Land And Actual Agriculture Land *Ratio Of Water Availability For Agriculture, 0.5, Potential Gap Between Desired Agriculture Land And Actual Agriculture Land*
- **Ratio Of Water Availability For Agriculture, 1)*
- *Units: Km2*

- *Forest= INTEG (-Deforestation-Forest To Urban Land Conversion+Reforestation-Road Land Clearing,11450.8)*
- *Units: Km2*

- *Forest Differential=Forest-Initial Forest Land*
- *Units: Km2*

- *Forest To Urban Land Conversion=MAX(0,Gap Between Desired Urban Land And Actual Urban Land/Construction Delay-Degraded To Urban Land Conversion-Cleared To Urban Land Conversion)*
- *Units: Km2/Year*

- *Gap Between Desired Urban Land And Actual Urban Land=Desired Urban Land-Urban Land*
- *Units: Km2*

- *Initial Agriculture Land= INITIAL(Agriculture Land)*
- *Units: Km2*

- *Initial Degraded Land= INITIAL(Degraded Land)*
- *Units: Km2*

- *Initial Forest Land= INITIAL(Forest)*
- *Units: Km2*

- *Initial Urban Land= INITIAL(Urban Land)*
- *Units: Km2*

- *Km2 Per Person For Food= WITH LOOKUP (Time,([(2007,0)-(2035,0.005)],(2007,0.00404686),(2035,0.004047)))*
- *Units: Km2/Person*

- *Land Degradation=(Agriculture Land/Land Degradation Time)*
- *Units: Km2/Year*

- *Land Degradation Time=50*
- *Units: Year*

- *Potential Gap Between Desired Agriculture Land And Actual Agriculture Land= (Desired Agricultural Land For Local Food+Desired Agricultural Land For Export)-Agriculture Land*
- *Units: Km2*

- *Proportion Of Agriculture INCOME FOR ROAD CONSTRUCTION AND MAINTENANCE WORK=*
- *1.5*
- *Units: Dmnl*

- *Reforestation= Reforestation Rate*Reforestation SW*
- *Units: Km2/Year*

- *Reforestation Rate=If Then Else (Time<2015,0, Degraded Land/Time Of Reforestation)*
- *Units: Dmnl/Year*

- *Reforestation SW=1*
- *Units: Dmnl*

- *Road= INTEG (Road Completion,0)*
- *Units: Km*

- *Road Area=Road*Road Width*
- *Units: Km2*

- *Road Completion=DELAY FIXED(Road Work Starts , Road Construction Time , 0)*
- *Units: Km/Year*

- *Road Construction Time=3*
- *Units: Year*

- *Road Land Clearing= Road Work Starts*Road Width*(1+Additional Area Needed For Road Construction Factor)*
- *Units: Km2/Year*

- *Road Length= WITH LOOKUP (Time,([(2012,0)-(2030,100)],(2012,0),(2013,80),(2029.9,80)))*
- *Units: Km*

- *Road Under Construction= INTEG (Road Work Starts-Road Completion, 0)*
- *Units: Km*

- *Road Width= 0.033*
- *Units: Km*

- *Road Work Starts=(Road Length-Road-Road Under Construction)*
- *Units: Km/Year*

- *Share Of Area Cleared For Road Construction Converted To Urban Land= 0.3*
- *Units: Dmnl*

- *Time Of Reforestation=3*
- *Units: Year*

- *Time To Deforest=1*
- *Units: Year*

- *Total Area Used For Road Construction=Road Area*(Additional Area Needed For Road Construction Factor)*
- *Units: Km2*

- *Total Desired Agriculture Land=Desired Agricultural Land For Export+Desired Agricultural Land For Local Food*
- *Units: Km2*

- *Total Employed In Road Construction=Road Under Construction*Workers Per Km Of Constructed Road*
- *Units: Person*

- *Total Employed In Road Maintenance=Road*Workers Per Km Of Road Maintenance*
- *Units: Person*

- *Total Income Generated For Road Construction And Maintenance=(Total Employed In Road Construction+Total Employed In Road Maintenance)*(Initial Household Income*Proportion Of Agriculture INCOME FOR ROAD CONSTRUCTION AND MAINTENANCE WORK)*
- *Units: Baht/Year*

- *Urban Area Per Person= WITH LOOKUP (Time,([(2007,0.005)-(2040,0.006)],(2007,0.0056855),(2035,0.0056855)))*
- *Units: Km2/Person*

- *Urban Land= INTEG (Cleared To Urban Land Conversion+Degraded To Urban Land Conversion+Forest To Urban Land Conversion,4749)*
- *Units: Km2*

- *Urban Land Differential=Urban Land-Initial Urban Land*
- *Units: Km2*

- *Workers Per Km Of Constructed Road=11.3*
- *Units: Person/Km*

- *Workers Per Km Of Road Maintenance=0.33*
- *Units: Person/Km*

The impact of interventions that relate to natural capital on well-being can be direct and indirect.

- Direct benefits include employment generation (e.g., new jobs for installing and maintaining renewable energy infrastructure), improved access to energy and water, increased food security (e.g., as result of ecological agriculture practices), among others.
- Indirect benefits include health (e.g., reduced occurrence of diseases linked to air or water pollution, adoption of healthy lifestyle), education (e.g., higher quality education and business skills resulting from capacity-building activities on innovative green techniques and technologies).

In this respect, the use of System Thinking and the creation of causal maps has several purposes. Firstly, it brings the ideas, knowledge and opinions of the participants together. Secondly, it highlights the boundaries of the analysis. Thirdly, it allows all stakeholders to reach a basic-to-advanced knowledge of the systemic properties of the issues analysed. Having a shared understanding is crucial for solving problems that touch upon several sectors, or areas of influence, which are normally found in complex systems. With broad stakeholder participation, and to effectively implement successful private-public partnerships among others, all the parties involved need to share the understanding of what factors generate the problem and what other can lead to a solution. As such, the solution should not be imposed to the system, it should instead emerge from it. In other words, interventions should be designed to make so that the system start working in our favour, to solve the problem, rather than generating it.

In this context, the role of feedbacks is crucial. In fact, often it is the system we have created that generates the problem, due to external interference or to a faulty design, which shows its limitations as the system grows in size and complexity. In other words, the causes of a problem are often found Unknown-2within the feedback structures of the system, and indicators alone are not sufficient to identify it and explain the events that led to the creation of the problem itself.

Scenario analysis also supports the creation of a shared understanding and support the establishment of an action-oriented approach. In particular, scenario analysis levels the paying field as it does not rely on history to general possible future paths. In other words, it does not extrapolate the past and does not expect past patterns (or the key drivers of past behaviour) to be still valid in the future. In this respect, scenario analysis promotes innovative thinking, looking at the dynamic properties of the system in a systemic way, without excluding any potential system response (knowledge or experience) at priori. Further, scenarios help decision makers identify elements of uncertainty. Often scenario planning focuses on the analysis of the impact of external events on our system, forcing decision makers to elaborate concrete contingency plans and exit strategies. The analysis of the effectiveness of these plans, normally carried within a diversified team or group of stakeholders, allows decision makers to simultaneously consider the political, social, economic and environmental dimensions of the system. Finally, scenario analysis creates expectations about future paths. As a result, indicators can be identified to monitor whether any of the observed paths is actually taking shape in reality (monitoring and evaluation). This allows decision makers to effectively and rigorously monitor the performance of the system.

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*As at January 2014

Greater Mekong green economy

US$4 BILLION

Retail value of Mekong River fisheries estimated at more than US$4 billion annually

60 MILLION

The Lower Mekong River provides the main source of food for 60 million people

+US$55 BILLION

The value that could be added cumulatively to the combined economies of Cambodia, Laos, Thailand and Vietnam by 2035 through implementing green economic growth policies that maintain natural capital over and above the value added by 'Business as Usual' economic development

80%

The Greater Mekong's natural capital directly supports 80 per cent of the region's population by providing vital ecosystem services

Why we are here
To stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature.

panda.org

The Greater Mekong region is one of the biologically richest places on the planet; its varied natural resources support the livelihoods and well-being of millions of people in mainland Southeast Asia. WWF-Greater Mekong – on the ground in Cambodia, Laos, Myanmar, Thailand and Vietnam – is working to conserve the region's biodiversity and build a secure and sustainable future for people and wildlife.