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LIVES: MODELING FOR CHANGE WITH NEXUS THINKING

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ABSTRACT
Nexus thinking is a new approach that recognizes the crucial interdependence of water, energy and food in an increasingly resource constrained world. Therefore there is a critical need to equip decision makers with research, capacity building and new tools that address Nexus challenges. LIVES is a research project which has developed and tested an integrated approach for linking indicators using scientific analysis and stakeholder inputs to support policymaking processes. The project objective has been to develop an approach, or a decision support system, which can be used to produce credible, evidence-based information that can help address growing food, energy and water demands in the context of unsustainable natural resource management, climate change impacts, large-scale infrastructure projects and a growing population. Our hypothesis is that only when food, energy, and water supplies are measured consistently, at multiple scales, with strong integration can decision makers visualize the linkages across sectors and make evidence-based decisions to improve lives, boost economies and preserve vital ecosystem services. For the first time, we have used Systems Thinking approaches to link indicators through a process of sharing knowledge on food, energy and water issues. Systems Thinking supports the creation of conceptual systems maps, where the interconnections existing among the key drivers of change in a system are identified and explicitly represented. We then developed a quantitative System Dynamics model for policy and investment design to solve the complex problems facing the Mekong Flooded Forest landscape in Cambodia. We used participatory processes that brought together experts, stakeholders and decision makers to capture their shared understanding of the problems they face and build their capacity to address current and future challenges. This resulted in the identification and prioritization of nine indicators that define the health of the landscape according to local stakeholders. The report card aggregates indicators of river basin health into a single 'grade' e.g. A, B, C etc. The model then allows us to simulate and identify the policy and investment actions that produce the best resilience outcomes (across sectors, actors and over time) over many possible futures. Together, these create a powerful indicator-based decision-support system.

Keywords: *green growth, system dynamics modeling, decision support system, landscape health, indicator-based approach to decision-making*

1. INTRODUCTION

The Linked Indicators for Vital Ecosystem Services (or LIVES) project, began in 2014 as a research project with the aim of piloting a new approach for linking food, energy and water indicators (things you can measure) to support decision making around food, energy and water challenges in different geographical contexts. An innovative research process was developed and piloted in an ecologically important region in Cambodia, called the Mekong Flooded Forest (MFF) landscape. Financed by the Luc Hoffmann Institute with the generous support of the Nomis Foundation, and in collaboration with WWF-Cambodia, WWF-US and the University of Maryland, the project has enabled scientists, policymakers and civil society to work together in new ways to find solutions to the problems arising from increasingly diminishing natural resources that households depend on for their day-to-day survival.

2. THEORETICAL APPROACH

LIVES is premised on Nexus thinking, an approach that recognizes the critical interdependence of food, energy and water. By seeking to understand how they interconnect, better understanding is reached that can support the development of interventions (policies or actions) that can meet the growing demand for food, energy and water in an increasingly resource constrained world (IIEA 2013). Activities in the LIVES project have also been based on the concept of 'sustainability science', building the capacity of local stakeholders by engaging them in the learning and experimentation of the research process (Miller, 2014). Scientific methodologies introduced as part of the LIVES project produced more valuable results as a result of inputs from local stakeholders at workshops. At the same time government officials, local researchers and NGO representatives benefited from training and Training of Trainers (ToT) training received on the tools introduced, enabling interactions to be mutually beneficial. Having the participation of local actors enables research processes to: integrate the best available knowledge; reconcile values and preferences; and create ownership for problems and possible solutions. In these processes, the role of researchers not only focuses on generating knowledge but also involves acting as brokers of knowledge, facilitators and change agents (Miller, 2014). Practical knowledge cannot be divorced from context. Learning processes consequently need to create meaning that is relevant to issues and challenges individuals face in their day-to-day lives.

The objective of the LIVES project was to address a problem: agriculture and energy production depend greatly on water; and water is affected by decisions people make in the way land is used and by increasing demand for water from a growing population. Food and energy are so deeply interconnected but decision-makers are not always aware of all the ways in which one sector impacts on the other, what threats this creates, or even what opportunities. If decision-makers could focus on measuring a small number of indicators that can be used to observe and monitor changes in the connections between food, energy and water in a given area, this can be used to understand which changes in those connections are causing problems or are unsustainable. This information can then be used to help prepare disaster-preparedness responses or sound actions to improve food security. Therefore by being better informed of the integrated nature of food, energy and water, better decisions can be made about how land and natural resources can be effectively used. Our hypothesis is that only when food, energy, and water supplies are measured consistently, at multiple scales, can decision makers visualize the linkages across sectors and make evidence-based decisions to improve lives, boost economies and preserve vital ecosystem services

3. A LANDSCAPE UNDER THREAT

The geographical focus of the project is an area in the north of Cambodia, designated the Mekong Flooded Forest landscape by WWF-Cambodia and officially named as such by the Royal Government of Cambodia in 2013. The landscape is a 56km stretch of land, covering the provinces of Kratie and Stung Treng comprising a population of 98,113 located in 96 villages. Figure 2 locates the landscape in Cambodia and highlights its ecological importance (WWF Cambodia, no date). The Mekong River that carves its way through the landscape is the most significant source of nutrition and livelihoods for local people as well as a vital contributor to the local economy, specifically agriculture, fishing, and nature-based tourism.

Unfortunately it is an area that faces many threats including the expansion of power generation, rubber plantations, and transport infrastructure. While there is a need for the landscape to develop and grow to provide employment for locals, reduce poverty and attract investment, landscape pressures from human activities affect environmental quality and local livelihoods. Large-scale, unsustainable and sometimes illegal exploitation of water resources, fisheries and forests such as encroachment, illegal fishing, and illegal mining activities are not only increasing but are impacting on natural resources, and people’s sources of food and livelihoods (Pearse-Smith 2012). If forest loss and fish depletion continue, this is likely to increase the vulnerability of local residents dependent on these, exposing them to food and livelihood insecurity, malnutrition and poverty.

The impacts of climate change are likely to exacerbate the situation. According to the US credit ratings agency Standard & Poor’s 2014 vulnerability index report Cambodia is considered the most vulnerable country in the world to the impacts of climate change (Reuters, 2014). The MFF landscape is projected to have annual temperature increases of up to 3.5 degrees Celsius by 2050, increases in drought periods by between 0.5 and 1.5 months by 2050 and increases in flooding due to increases in rainfall in the wet season (ICEM, 2015). Threats from unsustainable economic development activities combined with a changing climate create challenges that need well-designed policies and planning processes.

4. OPPORTUNITIES FOR CHANGE

Planning processes often take place in silos in policymaking generally as well as in Cambodia. Many countries have water use planning systems that do not take into consideration rapid increases in water needs e.g. for irrigated croplands, thus ignoring the resulting impacts that could include significant water shortages. At the same time, the same countries are often planning to meet energy needs with mixed portfolios including hydropower but without taking into consideration the impacts of a hydropower dam on water security, biofuels and food security. All of these plans are further compromised by the tendency not to systematically account for the impacts of carbon emissions and climate change on each of these processes. By failing to adopt an integrated approach to planning processes devastating impacts such as significant shortfalls in food and water could occur. Almost universally, decision makers at all levels are less concerned with single issues in their own right, and much more concerned with the impact of these issues on their bottom line - economic growth, social equity, geopolitical stability and national security. Therefore a systemic or Systems thinking approach, that identifies and understands the interconnections in a system (a social system or an ecosystem or a system that envelops the social, economic and environmental linkages in a given geographical area) could go some way to solving this problem.

Existing policies in Cambodia provide an opportunity to adopt approaches that aim to contribute to more sustainable modes of development. In 2013, Cambodia became the first developing country in Asia to adopt a national green growth strategy and strategic plan. Institutions to support the implementation of this strategy and plan have also been created, notably the National Council on Sustainable Development, representatives of which have provided significant contributions in LIVES activities. The National Strategic Plan on Green Growth focuses on: green investment and job creation, balancing economic development and environmental protection; and natural resources management, among other areas of focus. A new Environmental Code is also being developed which also supports the implementation of more sustainable development and management of natural resources. National government objectives therefore coincide with the objectives of the LIVES project.

5. SCIENTIFIC TOOLS AND METHODOLOGIES OF LIVES

LIVES project researchers used scientific tools and approaches to test a methodology and establish a decision support system that can be useful to decision-makers in Cambodia and around the world. Emphasis was placed on providing a more comprehensive understanding of the situational context and promoting more integrated approaches to decision-making.

5.1. A Systems approach

To understand and identify the key drivers of change in the MFF landscape, we used Systems Thinking. This approach to problem solving supports the creation of a conceptual map of a system (for example, this could be a social system, an ecosystem or a system that includes social, economic and environmental linkages altogether). A system map of a certain geographical area is created to identify and explicitly represent key drivers of change in the system. Having a shared understanding of what causes change and how to influence future trends helps decision-makers see pathways for managing the risks and opportunities that food, energy and water interconnections create. The identification of indicators was led by stakeholders (a cross section of society including: government officials at national and local level, civil society representatives, local university researchers, and farmers) and discussions not only resulted in a system map for the MFF landscape but also a shared understanding among the group of the drivers of change in this local context.

Once the MFF landscape system map was created, researchers and local stakeholders developed a quantitative system dynamic model to help design policies and investments that can solve the complex problems facing the MFF landscape in Cambodia. System Dynamics is an action research approach to studying complex systems, and the consequences of changes in the system, using mathematical modeling (Hirsch et al. 2007). System Dynamics models help us to understand underlying structures of systems, how they are governed and why they give rise to certain behaviours and outcomes (Bassi and Gallagher 2014). System Dynamic Modeling can provide a clear understanding of the quantity and quality of environmental "stocks and flows" on a given landscape (e.g. water availability is a stock, which is affected by precipitation and consumption which are flows, and water quality is a function of these and other factors that are also affected by stocks and flows). With its similarities to the integrated method GDP uses to measure the economy, System Dynamic modeling makes it possible to link food, energy and water indicators to the health, livelihoods, food and energy security of local people and to understand the interconnected causes and impacts of change in a given location. System Dynamic modeling is therefore a useful tool to provide decision support to policy-makers.

For LIVES, system dynamic modeling helped inform stakeholders how indicators link together when the MFF is seen as a system (for example how fish catch, agricultural productivity, income are interconnected), and using modeling to show how these key features of the landscape could change in the future. This was shown by modeling different future scenarios using locally sourced data and demonstrating change over time using graphs.

5.2 River basin health report cards

LIVES also produced an example of a river basin health report card in the MFF landscape, a more comprehensive version of which is likely to be implemented in the next phase of the project. The aim of a river basin health report card, a product of a partnership between WWF US and the University of Maryland, is to assess the current status of ecosystem health as well as the role of climate change and other external factors on the health of the river ecosystem (WWF US, no date).

The LIVES project facilitated the partnership between: system dynamic modeling and river basin health report cards resulting in the creation of 'future river basin report cards', an unprecedented initiative. These novel report cards incorporate the future scenario modeling results in the form of graphs that demonstrate the changes in river basin health over time according to different interventions. These future report cards present which actions can be taken now to improve the health of the river basin in the future. This additional information strengthens the report card's findings and policy recommendations, enabling decision-makers to be better informed on the future impacts of interventions. Because the model can identify the policy and investment actions that would enhance resilience across sectors, actors and over time and the report card can present this complex information in ways that are more easily digestible to policymakers, these two tools therefore complement one another to create an indicator-based decision-support system that can support decision-makers in making more informed decisions around natural resources.

6. PROJECT RESULTS

6.1. Result 1: A systems view of the MFF Landscape

Through a highly collaborative process involving many stakeholders, we created a systems map, otherwise known as Causal Loop Diagram (CLD), of the Mekong Flooded Forest (see figure 1) to capture the relationships between drivers of change in natural systems and the outcomes of these changes in this particular geographical landscape. By explicitly representing causal relations and incorporating environmental, economic and social indicators, the map provides a holistic overview of the local context. The purpose of creating this CLD is to explore the systemic nature of the MFF landscape, and to inform policy making at the provincial and national level so that actions can subsequently be identified and adopted that contribute to the well-being of the local population. Potential policy approaches/actions and their impacts are assessed using the following framework in which: issues or key components in a system (the MFF landscape in this case) are identified; the causes and effects of these issues/components are mapped using a systems approach; and then interventions are formulated and assessed in relation to their contribution to sustainable development. In the context of the MFF landscape, sustainable development is defined as a balanced path where a healthy food-energy-water nexus effectively enables the improvement of well-being of people at the local and regional level.

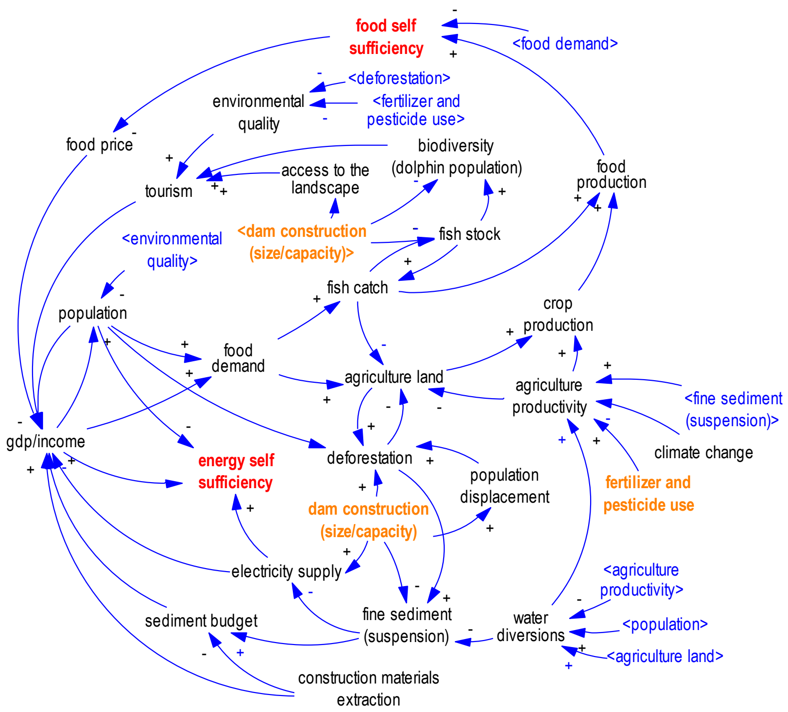

Figure 1. System map or CLD of the Food-Energy-Water Nexus in the MFF landscape

The MFF system map includes several variables, all interconnected through causal relations (blue arrows) and forming many feedback loops. These arrows link variables together with a sign (either + or −) on each link, indicating a positive or negative causal relation. Circular causal relations between variables form causal, or feedback, loops. These can be reinforcing or balancing. A balancing feedback loop tends towards a goal or equilibrium, balancing the forces in the system (Forrester, 1961). A reinforcing feedback loop can be found when an intervention triggers other changes that amplify the effect of that initial intervention, thus reinforcing it (Forrester, 1961).

In particular, a few dominant feedback loops can be found in the CLD:

- *Economic development:* as GDP and income grows, employment and investments will increase. As employment and income grows, so does population, resulting in higher food and energy demand. This is a reinforcing feedback loop. As long as resources are available (e.g. agriculture, land and fish) this feedback loop is likely to determine the primary force shaping future trends, especially because local food production is in most cases the most cost-effective food supply option.
- *Natural resources availability*: there is a finite amount of land in the MFF landscape. Population growth and the expected increase in food demand all require land (for settlements, crop and meat production). Land scarcity, as well as land management practices (e.g. agricultural practices, affecting crop yield and water pollution, among others) could prevent the expansion of local food production. If food self-sufficiency declines, it is likely to diminish the strength of economic development in the landscape as food imports will be required.
- *Pollution and environmental quality:* business as usual development (or continuing economic development at its current pace) will stimulate economic growth, but diminishes the availability of natural resources (as these are used unsustainably for the economic development activities). It also results in environmental pollution e.g. chemical fertilizer and pesticide use are likely to contaminate water supplies. As a result, the health of local populations and biodiversity is affected. Environmental quality affects soil productivity, tourism and the local population, ultimately indicating that the medium to longer-term impact of unsustainable practices might fully offset the short-term economic benefits they create.

- *Infrastructure:* the introduction of new infrastructure (e.g. roads and hydropower) is expected to trigger new (or strengthen existing) feedback loops. In the case of roads, market access will improve, as will tourism (reinforcing loops). In the case of hydropower, the availability of power will trigger more economic development and the associated infrastructure will facilitate the extraction of construction materials (reinforcing loops). These loops will in turn strengthen balancing ones, requiring food imports, which may lead to more investments in additional infrastructure to offset the reduction in water supply and to increase water purification.

The strength and even the dominance of all these feedback loops can be largely influenced by human decisions, such as the creation of a hydropower dam or mitigating measures. What is interesting is that changes in one of the diagram's indicators will affect several additional variables because each indicator is connected to another. As external interventions are introduced, the local context changes therefore the MFF is constantly evolving. Importantly, there are direct, indirect and induced outcomes of investment decisions that need to be taken into consideration before decisions are made. In the case of hydropower, dam construction and operation would impact land availability for agriculture production as a result of controlled inundations which may also directly impact the ability of fish to migrate from upstream to downstream, affecting fish populations downstream. This could then lead to fish imports or a replacement of fish consumption with more crop and meat consumption, both of which require land. The dam could also negatively affect economic development, if other food sources are more expensive than fish and if the indigenous freshwater dolphin population declines or even disappears due to reduced fish availability, changes in water quality and habitat disruption brought about by dam construction (an indirect impact), which would affect tourism arrivals (which would be an induced impact of the dam). But the dam could also have some positive impacts on economic development because of the higher access to a reliable source of electricity (an induced change) which it is assumed will happen.

The MFF landscape is not isolated from the region; it is affected by the development of surrounding areas (e.g. food demand and supply, transport of goods, tourism). Its ecological integrity highly influences the productivity of the whole Mekong Delta. Therefore the landscape's economic and environmental contributions to surrounding areas within Cambodia and beyond should also be taken into consideration when making decisions that will have significant direct, indirect and induced impacts.

6.2: Result 2: System Dynamic Model outputs

6.2.1: Overview of the MFF System Dynamic model

Because the model used was designed explicitly to analyse green economy scenarios (defined as scenarios that contribute to more sustainable approaches to economic development), it includes several sectors across social, economic and environmental dimensions. The effective integration of these sectors is made through the use of 'stocks and flows', which bring consistency to the mathematical formulations used to create the model. The model particularly focuses on the key 'capitals' of sustainable development, such as social and human capital, physical (or built up) capital and natural capital (stocks of natural assets such as air, soil, living things). The model customised to the MFF landscape is set up to simulate scenarios from the year 2000 to 2040. It presents annual results, but has a time step of approximately a month. The main stocks and flows included in the model are:

- *Human population,* influenced by birth, death and net migration (affected by the availability of settlement land);
- *Fish population*, influenced by breeding, mortality, net migration (affected by dam capacity) and catch (affected by fish demand);
- *Dolphin population*, influenced by breeding and mortality (affected by dam capacity);
- *Land* (settlement, agriculture, grazing and fallow/forest land), influenced by population and food demand (i.e. crops and meat);
- *Sediment*, influenced by water diversions (affected by population and precipitation), land clearing (affected by population and yield) and the extraction of construction materials (e.g. sand and gravel);

- *Hydropower dam capacity*, influenced by the assumed investment in capacity expansion (the decommissioning/discard of the capacity of the hydropower dam is not assumed to take place in the next twenty-four years due to the long life time of capital);
- *Road network length*, influenced by the assumed investment in capacity expansion and decommissioning/discard of roads; and
- *Hydropower economic indicators*, influenced by the capacity of the hydropower dam, and tracks its financial value and the cash flow resulting from operations. This financial value and cash flow includes revenues (affected by production and the price of electricity) and costs (affected by planned operation and management activities and sedimentation).

The same reinforcing and balancing feedback loops presented in the MFF CLD are also present in the model ensuring that the model includes the same inputs as the stakeholder-led CLD resulting in greater likelihood of acceptance of the results by local actors.

6.2.2. Scenario modeling outputs

Three main scenarios were simulated with the MFF model to better estimate the impact of the emergence of various trends (e.g. driven by policy and by climate change) on local livelihoods.

1. Business As Usual (BAU): assumes the current trends, and relative drivers of change, are remain dominant in the future. No new large or exceptional projects are implemented.
2. Reference scenario: assumes access to electricity increases, i.e. through the expansion of power generation capacity. The assumed expansion of capacity is in line with the current plans for the construction of the Stung Treng hydropower dam (980 MW of capacity, 4,870 GWh/year of production) in the north of the MFF landscape. In this case the required reservoir is expected to inundate 211km^2 which, it is assumed, will lead to 21 villages, or 10,617 people being displaced. 15% of the total electricity output is assumed to be distributed to the local population in this scenario. If other energy sources are considered, population displacement would likely not take place, but energy generation costs and capital investments would be higher. Infrastructure expansion (e.g. roads) is also assumed to take place with the expansion of power generation capacity.
3. Constrained water availability: the impacts of climate change are assumed to become increasingly tangible, with changes in the variability of precipitation and a marked shift in the rainy season. This scenario builds on the Reference case, and includes the challenges being faced by the agriculture sector due to the reduction in water availability (with the total amount of water being assumed to remain constant over time). Existing strategies to counter the potential reduction in yield are an expansion of agriculture land (or the cultivation of marginally productive areas) and the use of more water efficient techniques.

The BAU scenario shows that recent socio-economic development in the Kratie and Stung Treng provinces has begun to increase stress on natural resources. On the one hand, we observe more frequent periods of water shortages, which mean less water for irrigation and agriculture production and a decline in the productivity of fishing. Human activity (e.g. driven by population growth, see Figure 4) is directly impacting environmental quality, resulting in increased water pollution and a declining dolphin population. These signs indicate that carrying capacity, under current natural resource management practices, may have been reached in the MFF. As a result, any new growth in population or economic activity (represented by reinforcing loops) is likely to further exacerbate natural resources depletion and shortages (practically strengthening balancing loops); therefore the continued use of natural resources is unsustainable. This means that economic growth, under the current development trajectory, will happen at the expense of natural capital.

The trends forecasted by the MFF model for the Reference scenario, which assumes the improvement in access to affordable electricity through hydropower, show an important gain in economic growth, both due to construction work (and the availability of more and improved infrastructure) as well as to the increased access to electricity (Figure 2). Although, it is worth noting that economic gains are likely to be geographically variable. Local stakeholders have indicated that historical precedence has shown that the local labour force is excluded from the construction, operation and management of hydropower capacity and in previous cases, there has been a lack of electricity delivered to the local population. Therefore at provincial / regional level, the economic gains are likely to be smaller than the national gains. Projections also indicate that this economic growth comes at a cost. The increase in food demand (for local consumption and for export) will lead to further land conversion by 2040. The expansion of land conversion for agriculture will undermine critical ecosystem services; reduce water that could be available for other uses such as for biodiversity or existing / additional hydropower generation (especially when considering that water supply will already be affected by climate change impacts). This could ultimately lead to a higher dependence on imports (e.g. for fish, see graph located on the left in Figure 3), a reduction in biodiversity (e.g. dolphin numbers, see graph located on the right in Figure 3), and increased vulnerability to climate change impacts. Therefore under the Reference scenario, an increase in energy availability leads to increasing (direct and indirect) challenges on food self-sufficiency and water availability. The economic development brought about by the expansion of infrastructure is considerable, and will help reduce monetary poverty however the impacts of development are likely to be uneven. As a result of the reduced natural resources, inequality is likely to increase and the vulnerability of the rural poor is likely to increase. The key question that emerges from the simulation of the model is whether this type of development, and transformation of the local economy, is desirable. This is an important consideration to make, because with every transition there is likely to be an improvement of certain livelihoods, as well as a disruption of others.

The results of the <u>Constrained Water Availability</u> scenario are also significant. When climate change impacts on water availability are considered in addition to the implications of the hydropower dam, the results are sizeable. The reduced water availability results in a marked decline of agricultural production (21% on average during the period 2016-2030) relative to the Reference scenario) (Figure 4). In addition, the forecasted trend of more extended periods of drought leads to less efficient use of land, therefore deforestation is likely to increase to convert land for agriculture.

Natural capital needs to be sustainably used and managed for economic growth to continue and for growth to be inclusive, for the benefit of all. Therefore a balance between the economy and the environment is needed. To achieve this harmony, economic development objectives should not maximize production at the expense of natural capital. Instead the goal of development should be to maximize the health of ecosystems, so that production can increase sustainably. In other words, to effectively support a growing population in the MFF landscape, the carrying capacity of the MFF should increase. Interventions can be introduced to increase the carrying capacity of the landscape, such as improving water efficiency in the agriculture sector and establishing environmental flow standards (e.g. ensuring that a certain amount of water can flow through the river to support critical ecosystem services), see graph on the right in Figure 4. Both of these interventions would contribute to balancing growth with the necessary food, energy and water goals at the landscape level. Increasing carrying capacity however requires continued efforts and sustained political will.

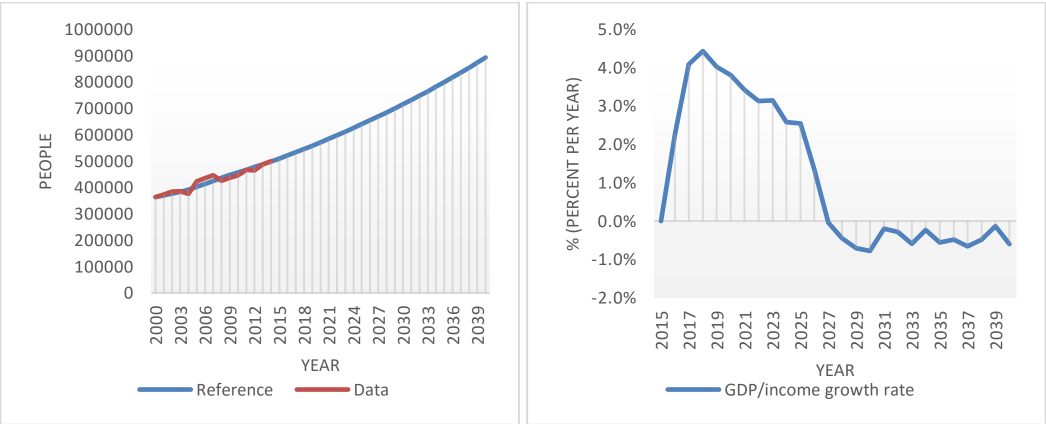

Figure 2. Reference scenario graphs relative to BAU, 2000-2040, for population (above left) and GDP/Income growth rate (above right).

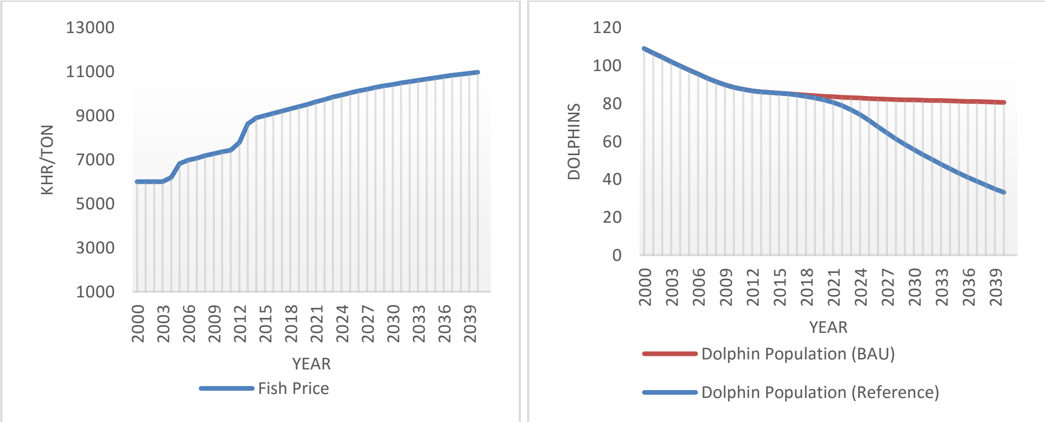

Figure 3. Reference scenario of fish price, 2000-2040 (above left); BAU and Reference scenario of dolphin population, 2000-2040 (above right).

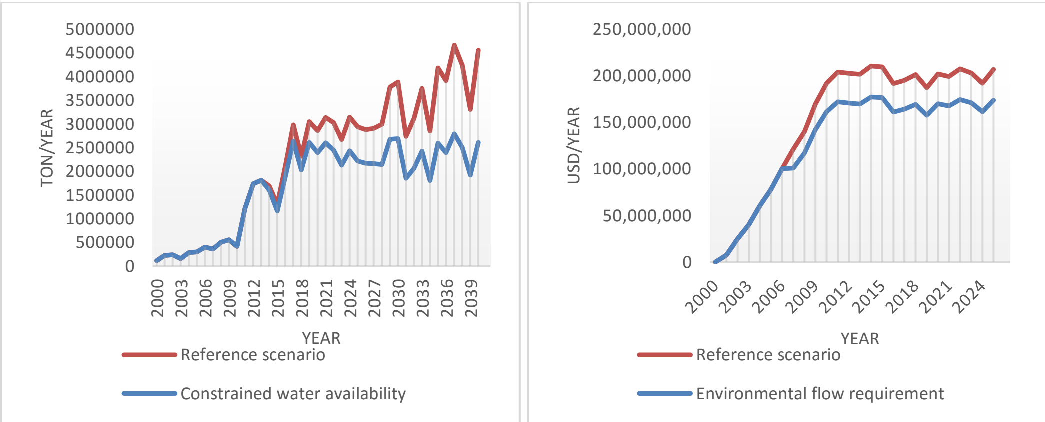

Figure 4. BAU and Constrained Water Availability scenarios of agriculture production 2000-2040 (above left), Reference scenario and inclusion of environmental flow standards as an additional scenario for hydropower dam operation and management costs, 2000 – 2040 (above right).

6.3. Result 4: An Example MFF Landscape Health Report Card

Report cards are a useful tool for natural resource managers and government to track and plan for the sustainable management of natural resources in a particular geographical area such as a landscape or river basin. Report Cards have been undertaken in a number of river basins around the world. The process of developing a report card requires active stakeholder participation, and a step-by-step process involving: the stakeholder-led identification and prioritisation of indicators to determine the health of a specific geographical area (usually a river basin); data collection on indicators selected; research and consultation to determine the indicator thresholds; scoring of indicators according to these thresholds to determine how 'healthy' an indicator is; the aggregation of the indicator scores into an overarching score e.g. A, B, C etc. to show the current health of the landscape or river basin; and communication of this information in a short, easy to understand report card.

Time limitations prevented the undertaking of a full MFF Landscape Health Report Card but an *example* MFF Landscape Health Report Card was developed. The process to produce the Example Report Card (for short) involved: firstly consulting with local stakeholders who identified the landscape's values and threats; secondly, indicators were selected based on this information; thirdly, data was sourced from sectoral provincial departments of Kratie and Stung Treng (the data was then assessed for suitability); fourthly, the indicators for which there was data were given a grade. For the purposes of this example report card and based on available information, four indicators were used to carry out a pilot assessment of the health of the Mekong river basin in the MFF landscape. These are: rice availability (to represent human wellbeing), ratio of paved to unpaved roads (to represent the status of the economy), forest cover (to represent remaining natural resources) and dolphin population (as a sign of environmental quality). Based on these four indicators, the Example Report Card gave the health of the MFF an overall grade of B. However the individual indicators that made up this score varied significantly with only 16% of the road network in the region being paved. The percentage of paved roads is showing a positive trend, with only 3% of roads being paved in 2002. Rice availability is also showing an increasing trend with current production exceeding minimum rice requirements for people in the region (the data did not show what percentage of this rice is exported or not available to the local population). Declining trends were observed however in forest cover and dolphin populations, despite both indicators currently scoring well. The government data showed that since 2002, there has been a loss of 28% of forest cover (approximately 274,000ha loss) and an estimated 25% loss of the dolphin population. Data and time limitations prevented a more complete assessment of the ecosystem health of the MFF, which would be required for more accurate results.

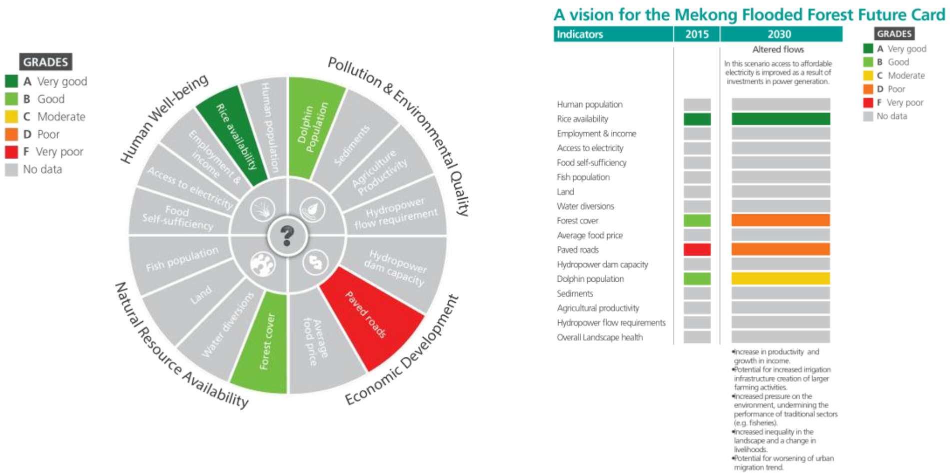

Figure 5. Wheel of indicators in Example MFF Report Card (above left); 'Future Card' in MFF Report Card, in which two scenarios are portrayed (above right).

Modeling the health of the river in the MFF landscape under different future trajectories is a new addition, carried out by integrating the model scenarios. The future scenarios are presented in the report card in a simplified manner that makes it useful for policymakers to understand and to be aware of scientific, evidence-based information that can help to inform decision-making around food, energy and water issues. By analysing three potential future scenarios: 1. no change in the system; 2. altering the water flow of the system; and 3. altering the flow with predicted changes in climate, the model outputs were able to support the creation of future cards, predicting report card scores based on different options, and recommending the path that is best for the landscape and its people as a whole.

7. CONCLUSIONS

The LIVES project has greatly benefited from the regular and direct involvement of local stakeholders. It has been essential in better identifying the main drivers of change and understanding how they interacted to shape historical trends and influence the effectiveness of future investments and policies. Stakeholders have ranged from government officials to farmers, all of which have the potential to make valuable contributions to the understanding of landscape dynamics. Directly involving technical experts has facilitated and supported the identification, collection and use of data and literature for model calibration and validation. They also play a very important role in the training for government officials and local stakeholders. Providing training to locally based university representatives, government official as well as locally based WWF staff is also crucial to build capacity. Training local university representatives transfers and embeds knowledge in local institutions that can sustain these approaches and provide training to government representatives on the modeling process going forward.

The results of the model indicate that the landscape has reached (or is close to reaching) its carrying capacity. This is evident from the analysis of the interactions between several stocks and flows (across social, economic and environmental dimensions). Given the trade-offs emerging from the analysis, and how intrinsic to economic development natural resources are, alternative development paths need to be explored to ensure that economic performance can improve while maintaining equity and access to natural resources as well as avoiding side effects, such as environmental degradation and food price spikes.

The model results also indicate that investments that are currently planned to benefit national economic development are likely to lead to negative impacts at the landscape level, which is likely to lead to additional costs (thus reducing the expected positive impacts of the investment) and also to growing inequality in the landscape. It is therefore recommended to design intervention options that not only support socioeconomic development at all levels but also introduce ways to increase the carrying capacity of the landscape. Natural capital should therefore remain a critical enabler of (inclusive) growth, and development should not take place at the expense of the environment.

In the two years the LIVES project has taken place, it has introduced concepts and approaches that challenge conventional approaches to decision-making. System dynamic modeling has helped local stakeholders visualize and understand the interconnectedness of the landscape and provided a better understanding of how decisions made today will impact on the economy and natural environment in the future. The enthusiasm of policymakers at national and provincial level to contribute to the project's outputs and learn these new approaches and build their own capacity, is evidence of an appetite for this type of decision support system for better informed decision-making in Cambodia. In the closing remarks of the a LIVES workshop in July 2016, Deputy Provincial Governor for Kratie Province, Cambodia announced his support and appreciation for the indicator-based decision support system introduced stating "we can incorporate indicators into the stages of the policy development". He continued that the LIVES example report card "for all of us is unique. It brings to us the vision, one common vision for us. We can use it as a compass". With the implementation of the approach presented, it is expected that the understanding of linked indicators will improve, which would lead to the reduction of negative impacts of decisions and improve the effectiveness of policy making both at national and provincial level. This would allow Cambodia to attain its national development goals, and SDG requirements, at a quicker pace and at a lower cost. LIVES will therefore continue to work with decision-makers to support planning processes in achieving their sustainable development objectives.

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