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Green economic development in Lao PDR: A sustainability window analysis of Green Growth Productivity and the Efficiency Gap

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ABSTRACT

A novel 'Sustainability Window' (SuWi) approach is applied for simultaneous analysis of the pillars of sustainable development; social, environmental and economic, of Lao PDR. This new method employs a variety of indicators for a comprehensive and holistic analysis of sustainable development and green inclusive economy. The analysis is grounded in the assumption that economic development is required for social development, but that simultaneously development needs to be guarded or limited to protect the environment that underpins it. As all three dimensions of sustainable development are interlinked, a comprehensive analysis requires an analytical approach that is simultaneous. The analyses provide information on minimum levels of economic development that are needed to fulfil social sustainability criteria, in tandem with the maximum economic development that avoids breaching environmental sustainability criteria. If actual economic growth lies between these minima and maxima, we can interpret that development is more sustainable with respect to the relationships embodied by the selected social and environmental indicators. The main source of data is the database of the Sustainable Society Index (SSI) developed by the Sustainable Society Foundation (SSF). The indicators used by SSI have been chosen for the Sustainability Window analysis as they can be used to assess both 'weak' and 'strong' interpretations of sustainability. Weak sustainability is defined operationally as no increase in the environmental or carbon emissions intensity of the economy, while strong sustainability is defined as no increase in absolute emissions. Further, a novel Environmental Efficiency Gap analysis has been included in the Sustainability Window. This provides information about the necessary improvement in GDP production efficiency with respect to environmental emissions. Sustainability Window combined with Environmental Efficiency Gap analysis, provides critical knowledge for planners and decision makers. It provides strategic indications of how to aim for social and environmental sustainability through economic investment and growth targets. These new methods can be used in transdisciplinary research of sustainable development and can also assist in national and regional comparisons. In the case of Lao PDR, the analysis needs to be broadened for more fundamental understanding of the gaps and weaknesses. SuWi can be used to assess the sustainable development needed to address the Sustainable Development Goals by 2030. The SuWi does not provide direct policy recommendations as such, but helps to inform decision makers about the direction of development pathways towards these key goals.

1. Introduction

The pursuit of economic growth as the prime development goal has been roundly discredited for both developed and developing nations alike (Stiglitz et al., 2009; Anand and Sen, 2000; Sachs,

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2016). It is widely accepted that successful development planning and decision-making requires an integrated approach that balances all of the sustainability dimensions; the social, the environmental and the economic (Fleurbaey et al., 2014). Recently, development actors have begun to refer to more nuanced objectives of *green economy, green economic development, low carbon development, sustainable development* and/or *climate compatible development* (Urban and Nordensvärd, 2013). The modern concept of sustainable development was first introduced by the Brundtland Commission report "Our Common Future" (WCED, 1987), and since then, other variants have emerged. Low carbon development addresses climate change as the core challenge of environmental sustainability, emphasising mitigation action, but not referring to broader environmental challenges (Skea and Nishioka, 2008). Climate compatible development, on the other hand, underlines the actions of adaptation to climate change. Green growth or green economic development focus on greening consumption, production, business and markets. Hence, it underscores the adoption of the principles of sustainable development in economic development through a growth objective (Urban, 2011). According to UNEP (2011) and popular in the current economic discourse, a green economy is one "*whose growth in income and employment is driven by public and private investments that reduce carbon emissions and pollution, enhance energy and resource efficiency, and prevent the loss of biodiversity and ecosystem services*". This necessitates the conservation and rebuilding of natural capital, especially for those in poverty, whose livelihoods and security depend strongly on nature and its resources. This further requires additional investments and targeted public expenditure, policy reforms and regulation changes (UNEP, 2011).

Sustainability and greening the economy is currently central to many policy making efforts thanks to various global initiatives, such as UNEP's Green Economy Initiative (GEI) of 2008 (UNEP, 2011). There, progress is sought through policymaking that supports environmental investments as a way of achieving sustainable development. In the Rio+20 agenda "*green economy in the context of sustainable development and poverty eradication*" was recognised as a tool for achieving sustainable development.

There are different issues that arise in developed and developing countries with respect to greening economic development. In more developed countries, per capita environmental footprints require a focus on reduction to more sustainable levels, within a framework that also enhances, or at least maintains human wellbeing, and, addresses in-country inequality. In less developed countries, while there are elites and middle classes whom are also over-consuming (Pow, 2011; Gupta, 2011), the major issue is persistent poverty and deprivation that could be fought with inclusive growth and sustainable consumption to meet basic human needs and facilitate human capabilities. The coarse prescription of 'growth at all costs' is unsuitable for both developed and developing countries. Implementing and developing indicators and establishing methods that address sustainability synergies and trade-offs is consequently a priority requirement in balancing development and delivering on the UN Sustainable Development Goals (SDGs).

In the past decades there has been a strong effort towards tracking sustainability with various sustainability assessment tools developed from indicator/indices, product related or integrated assessments (Waas et al., 2014). Internationally the leading effort towards tracking countries' performance on sustainability was led by the United Nations in establishing a core set of 17 Sustainable Development Goals with 232 indicators (UN/SDG, 2016). Approaches such as the SDG indicators or, Sustainable Society Index (SSI) are geared towards influencing at sustainable development mainstreaming through decision and policy making processes. The amount of material and immaterial investments required for sustainability transformation is attracting increasingly attention and capturing these synergies and co-benefits is at the core of sustainable development mainstreaming.

Sustainability analysis can be sub-divided into two categories: assessments and indicators. It can be analysed from the perspective of one dimension alone; economic (e.g. cost-benefit analysis), environmental (life −cycle analysis, ecological footprint or resource accounting) or social (sustainable livelihoods approach or human/social capital measurements). However, this approach fails to comprehensively address all three dimensions of sustainability (Waas et al., 2014). In a nutshell the "*attractiveness of sustainability indicators lies in their ability to structure, to summarize, and condense the sustainability complexity to a manageable amount of meaningful information",* but these still need to be supported by other measures and inputs to ensure sustainability decisions (Waas et al., 2014). Complex problems that relate to the nexus of unsustainable environmental and socio-economic development require new robust research methods that robust holistic analysis. Achieving both social progress and balance in development calls for strategic policy approaches informed by holistic analysis. Sustainability Window analysis (SuWi) is a new method proposed by Luukkanen et al. (2015), which facilitates such integrated analysis of change in the different dimensions, as a coherent and comprehensive framework of sustainability. SuWi responds to the complexity of 'wicked' sustainability problems with the parsimony of a robust unified framework. However, it could also assist in grasping opportunities for progressive future change that balances competing development concerns and captures win-wins. Sustainability Window SuWi analysis builds on the Advanced Sustainability Analysis (ASA) framework of Kaivo-oja et al. (2001a; 2001b; 2002).

In many countries in the Global South policy prioritises 'growth' and 'development.' This seeks to increase factors such as employment levels, incomes, living standards and consumption levels, while also lifting people out of poverty. However, a focus solely on economic growth is by no means guaranteed to achieve these outcomes. Unintended consequences of growth policies may even harm these objectives. Some documented phenomena include growth that is jobless, growth that does not increase human wellbeing or growth that undermines the environment that supports wellbeing and even the foundations of growth itself. Much of the development literature has moved beyond the rights-based approach (Rawls, 1971) and the utilitarian view (Nozick, 1974) to improving human capabilities and environmental sustainability as more nuanced and appropriate goals (Stiglitz et al., 2009). The potential within the countries of the Global South is thus to prioritise improvement in human development outcomes, while avoiding the unnecessary social and environmental burden that often emerges as a consequence of unlimited growth efforts.

As development 'takes off', Least Developed Countries (LDCs) such as Lao PDR, can theoretically use green growth to improve economic prospects while at the same time delivering better development outcomes. They can also avoid sub-optimal development options with hidden costs while they are improving standards of living and human wellbeing. Much infrastructure in countries such as Lao PDR is not yet built, and therefore it is not rigidly locked-in to conventional development pathways.[1] Therefore, alternative more beneficial pathways are available and will require the analysis and policy that facilitates their realisation.

[1] The definition of development pathways of Sathaye et al. (2007: 696) continues to be useful: 'Development paths are defined here as a complex array of technological, economic, social, institutional, cultural, and biophysical characteristics that determines the interactions between human and natural systems, including consumption and production patterns in all countries, over time at a particular scale.

In order to define sustainable development pathways, it is necessary to grasp how the social, environmental and economic dimensions are intertwined, and how direct and indirect factors impact its evolution. SuWi Analysis (Luukkanen et al., 2015) is a novel method that can be used to aid decision making and planning while considering the nexus between environmental, social and economic aspects of development. It functions as a multidisciplinary tool that considers all three dimensions simultaneously, as originally intended by Brundtland (WCED, 1987). The 'SuWi' tries to overcome the risks of approaching and tackling issues of sustainable development in a narrow, compartmentalised and separate manner. Such a separation can distract from, or underplay the fundamental connections between the economy, society and the environment. These approaches lead to assumptions that trade-offs can be made between these three pillars, in line with weak views on sustainability, that built capital can replace or substitute natural resources and systems (Giddings et al., 2002; Neumayer, 1999). The discussion of the Framework for Strategic Sustainable Development (see e.g. Korhonen, 2004; Baumgartner and Korhonen, 2010; Cristen and Schmidt, 2012) provides another important field for approaching sustainability. The framework of Sustainable Interdependent Networks (Amini, 2018) provides another interesting approach to study the optimal operation of large-scale complex interlinked systems.

This paper examines, on the basis of the current global sustainable development agenda, how Least Developed Countries (LDCs) like Lao PDR can track their sustainability efforts in the transition towards a greener and more inclusive economy. The paper builds upon the current sustainability assessment tools, namely SSI indicators developed by the SSF, to introduce a potential new tool developed by Finland Futures Research Centre, Sustainability Window (SuWi) Analysis. Background knowledge on the study context is given in section 2. The methodology of SuWi Analysis is explained in detail in section 3. The results in section 4 present the analytical outcomes, in the context of the economic, social and environmental performance Lao PDR, on its path towards green and inclusive economy. This provides insight into current understanding of sustainability assessment challenges and the application of the SuWi tool. The paper discusses the challenges and enabling environment that are crucial for truly sustainable development in section 5, and concludes with further improvements and possibilities for the future work in section 6.

2. The study context of Lao PDR

Lao Peoples Democratic Republic (Lao PDR) provides an appropriate case study to test the SuWi analysis approach. The context of Lao PDR is briefly discussed here. Although landlocked, Lao PDR's population grew strongly between 2005 and 2015, from 5.6 million to 6.49 million (Lao PDR, 2016). In addition, GDP growth has also been high, at 7.9 percent per annum in the last five years. The national growth target was set at >8 percent in the 7th National Socio-Economic Development Plan (NSEDP) (Lao PDR, 2016). This strong and sustained economic growth is gradually changing the economic structure of the country, from natural resource-based development, towards industry and the services sectors. According to the 8th NSEDP, this has resulted in increased employment and improved well-being of the people; with low inflation rates; satisfactory levels of production in agriculture, industry and service sector; increased imports, exports, and public and private investment.

At the same time, poverty rates have decreased from 27.6 percent in 2008 to 23.2 percent in 2013 (Lao PDR, 2016). The long term objective of graduating from Least Developed Country (LDC) status has progressed well, and in 2011, the World Bank improved the status of Lao PDR from the Low Income Country bracket to that of a Lower-Middle Income country. Lao PDR is now ranked 138 out of 188 countries on the Human Development Index (HDI). The HDI has increased from 0.397 in 1990, to 0.586 in 2015, an increase of 47.6 percent. This has lifted Lao PDR to a medium level of human development (UNDP, 2016; Lao PDR, 2016).

By international comparison, Lao PDR has very low GHG emissions with an estimated 21.8 $MtCO_2e$ in 2010. In the global context, its historic contribution to climate change has been minimal, accounting for approximately 0.1 percent of total GHG emissions globally (WRI, 2014). However, the country is also highly climate-vulnerable and is suffering from the adverse impacts of climate change. The country has taken ambitious steps towards increasing its resilience towards climate change while reducing its emissions in its Intended Nationally Determined Contribution (INDC) from 2015 (Lao PDR, 2015). As part of its mitigation and transition plans, the country is seeking to increase forest cover for carbon sequestration and also to move to nearly 100 percent renewable (yet controversial) electricity generation. This plan includes export of hydroelectric energy to neighbouring countries, as 'the battery' of Southeast Asia. The electricity network has been expanded almost throughout the country, with household access to electricity at 89.6 percent in 2015. As part of its Nationally Appropriate Mitigation Actions (NAMA) key measures include rural electrification program, especially in remote areas. Furthermore, the National Forestry Strategy to 2020, the Renewable Energy Development Strategy and implementation of transport focused improvements, are all part of the country's mitigation efforts.

The policy framework and long-term vision documents, as well as the NSEP's, have a strong emphasis on 'green inclusive growth'. In the Vision 2030 document, Lao PDR foresees itself to be "*ranked as a developing country with upper-middle income and with innovative, green and sustainable economic growth*" (Lao PDR, 2016). The ten-year Socio-economic Development Strategy for 2016–2025 emphasises *inclusive and sustainable growth* as being the way forward (Lao PDR, 2016). The Lao PDR 8th National Socio-Economic Development Plan (NSEDP) 2016–2020 emphasises the three pillars of the Green Economy; *inclusive growth, investment in human development and protecting the environment* (Lao PDR, 2016) as priorities in its transition from Least Developed Country (LDC) status.

3. Data and methods

Sustainability Window Analysis (SuWi) is a tool for assessing the sustainability of development in all three of its dimensions simultaneously (social, environmental and economic). SuWi allows the identification of minimum and maximum economic growth rates, a 'window' that characterises the economic development path that leads to more sustainable social and environmental outcomes. The analysis does not refer to the absolute level of sustainability, which usually cannot be fully prescribed, but determines whether the direction of change is towards a more sustainable state or not. SuWi can be used in sustainability transition analyses and gives realistic results for decision-makers to use. The technique of SuWi analysis is flexible in that the analyst is free to select the hierarchy level of indicators for the analysis (see Mulder and Biesiot, 1998: 10–16).

In this article we use the concepts of the 'Strong Sustainability Window' and the 'Weak Sustainability Window,' referring to the concepts of strong and weak sustainability (see e.g. Neumayer, 1999; Kaivo-oja et al., 2001a,b; Vehmas et al., 2007; and Kaivo-

Table 1
Indicators used as examples for Sustainability Window analysis. The indicators are indexed for the analysis. The indicators are from SSI database (van de Kerk and Manuel, 2014) and World Bank database (World Bank, 2016a).

Economic	Social	Environmental
GDP	Sufficent food	GHG emissions (strong)
	Healthy life years	GHG emission intensity (weak)
	Social inclusion	Consumption of global hectares (strong)
	Sufficient drink	Global hectares consumption intensity (weak)
	Gender equity	Unsafe sanitation
	Income distribution	Energy (strong)
	Good governance	Energy (weak)
	Education	

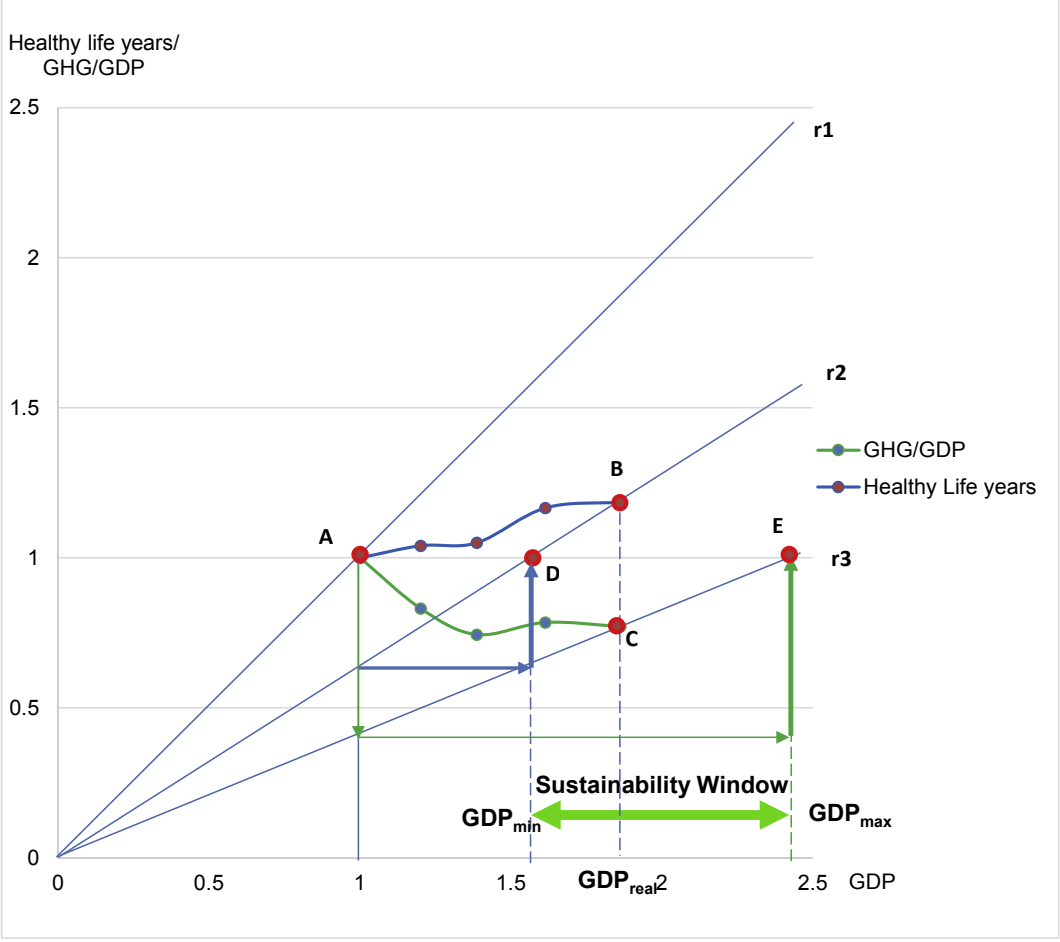

Fig. 1. Weak Sustainability Window for Lao PDR using 'Healthy life years' as social indicator and 'Greenhouse Gas emission intensity' (GHG/GDP) as the environmental indicator and GDP as the economic indicator for the analysis of sustainability.

oja et al., 2014).[2] Global climate justice is a relevant question in the context of LDCs and appropriate emission mitigation efforts. In LDCs, environmental loading and emissions are often significantly lower than comparators that are more highly developed. In Lao PDR, GHG emissions per capita were only 0.4 tons of CO_2eq in 2006 (the base year of the analyses in this article). Demanding that LDCs such as Lao PDR cut down emissions, while the global average still remains as high as 4 tons per capita, raises ethical questions of development equity. Nationally Appropriate Mitigation Actions (NAMAs) have been widely recognised as a powerful agent for transformational social, economic, and environmental change. NAMAs began as a way for developing countries to contribute towards global climate change efforts while moving their economies on sustainable development pathways. In addition to measurably lowering emissions, NAMAs are proven to enhance food security, improve public health, increase energy supply, and promote sustainable development (see e.g. Lao PDR, 2015). In OECD countries, the per capita emissions figure is much higher, while the general sustainability level is approximated to be about 1.8 tons per capita (Kuntsi-Reunanen and Luukkanen, 2006). This is why using the

[2] Defining 'sustainability' is inherently a political process that ascribes value to rights, welfare and capabilities, both across and within generations. It also ascribes value to the natural world, whether it is valued for anthropocentric reasons through ecosystem services to humans, or for eco-centric reasons, through the value of the environment in and of itself.

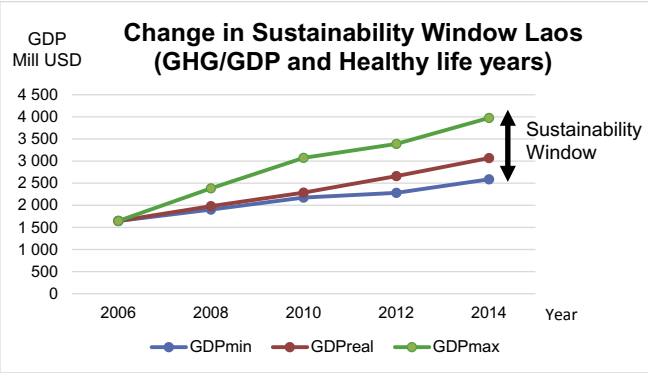

Fig. 2. The changes in the Sustainability Window in Laos for years 2006–2014 using 'Healthy life years' as social indicator and 'Greenhouse Gas emission intensity' (GHG/GDP) as the environmental indicator and GDP as the economic indicator for the analysis of sustainability. During the observation period the real GDP growth has been within the Sustainability Window defined by used indicators.

weak sustainability criteria in the analysis is necessary.

The Sustainability Window approach is a useful tool in transdisciplinary sustainability science, because it makes *key transition paths visible for decision-makers and stakeholders* (see Komiyama and Takeuchi, 2006; Kajikawa, 2008; Brandt et al., 2013). The analyses can be seen as governance tools for transition management (see Loorbach, 2002; Loorbach, 2007; Kemp and Parto, 2005). There is a clear value added in making transition and backcasting scenarios in sustainability science. With the SuWi method both transition scenarios and realistic backcasting scenarios can be built, because the transition paths and associated backcasting targets can be identified (see Mulder and Biesiot, 1998; Sondeijker et al., 2006). Reflective evaluations of sustainable development can be developed using the SuWi approach (see Voss et al., 2006; Quental et al., 2011).

Following the framework of the SuWi approach, three different indicators require identification; environmental, social and economic. The indicators can also be composite, but they must be compatible, and it is important that the analyst understands the implications of the choice of indicators, and prioritisation of one indicator over another. In this SuWi analysis the familiar, widely used indicator of GDP[3] is chosen for the economic dimension, requiring identification of a compatible indicator for the other two dimensions. It is not possible to apply the Human Development Index (HDI) as the indicator for the social dimension because it cannot grow beyond 1. Indicators describing annual changes (e.g., annual percentage change) cannot be used in the analysis. Other absolute measures are required for compatibility with GDP.

SuWi analysis determines the maximum economic development needed to fulfil the environmental sustainability criterion and the minimum economic development needed to fulfil the social sustainability criterion for development. These maximum and minimum economic development parameters define the "window" within which the economic development is sustainable.

The SuWi analysis assesses the maximum sustainable economic growth in relation to the change in the environmental indicator. This means that the maximum economic development (GDP) is determined so that the related environmental change is towards a more sustainable state. In practice this means that e.g., the emissions should not increase if we use Strong Sustainability criterion. In the Weak Sustainability criterion, the emission intensity, as emissions per unit GDP, should not grow.[4]

The SuWi analysis also assesses the minimum sustainable economic growth in relation to change in the chosen social indicator. This means the minimum economic development is determined so that human wellbeing, as measured by the chosen social indicator, does not decrease. The difference between the maximum and minimum economic development defines the width of the Sustainability Window. Using the SuWi analysis it is possible to determine whether the development in the selected nation is within or outside the sustainability window determined by the selected indicators. The SuWi analysis can, of course, be an algorithm for global sustainability analyses and it can be integrated with the new sustainability indicator system of the United Nations (UN) (UN, 2017).

The implementation of the SuWi analysis with respect to Lao PDR is explained in the following section. The SuWi analyses the development of Lao PDR with respect to three pillars of the Green Economy form UNEP (2011); (i) low carbon development, (ii) resource efficiency, and (iii) social inclusion. As a sensitivity analysis, alternative indicators are also used for comparison against results with the chosen indicators. This also aids in consideration of issues pertaining to ease of use and interpretation, and provides a broader view of the Green Economy development.

Several different sustainability indicator sets have been developed by international organisations, research centres and statistical offices (see comparison by Schoenaker et al., 2015). In this research, the Sustainable Society Index (SSI) of van de Kerk and Manuel (2014) was used as the data source for the analysis. The SSI integrates indicators of Human Wellbeing, Environmental Wellbeing and the Economic Wellbeing based on the definition of sustainable development elaborated by the Brundtland report. The period of analysis is from 2006 to 2014, the period for which the SSI data is available. In addition, we have also used the World Bank database for the indicator of 'Social inclusion' CPIA database (Country Policy and Institutional Analysis) in order to explicitly include this green growth dimension in the analysis (World Bank Group, 2016). World Bank data is also used for the 'Forest rent' indicator (World Bank, 2016a). For the SuWi analyses we have indexed the indicators from SSI database and the World Bank database to have the value 1 for the base year 2006 of the analysis. The indicators used in the analysis are shown in Table 1. The values of the indicators are given in Appendix 1.

In Fig. 1, the Sustainability Window is constructed using Healthy Life Years as the social indicator, GHG emission intensity (GHG/GDP) as the environmental indicator and GDP as the economic indicator. In the example we use the Weak Sustainability criteria, as is indicated by the intensity indicator used to describe the environmental dimension (emissions intensity). The time series data for the indicators are indexed to have a value of 1 for the base year 2006 of the analysis. Healthy Life Years and the GHG/GDP are expressed (on the y-axis) as a function of the GDP development (on the x-axis) for the different years 2006–2014 available in SSI database. The development of the Healthy Life Years is expressed with the blue line and the GHG/GDP with the green line.

In the base year situation (point A) the line r1 describes the Healthy Life Year productivity of GDP as well as GHG/GDP productivity of GDP. In the final year of the analysis, 2014 (points B and C) the lines r2 and r3 describe these productivities indicating that

[3] Gross Domestic Product (GDP) is a monetary measure of the market value of the flow in goods and services produced in a period, quarterly or yearly.

[4] In line with its very low emissions per capita, its low historical contribution to climate change and it's need for economic development, the Lao PDR INDC does not determine an emissions peak, or an intensity or absolute emissions target (Lao PDR, 2015).

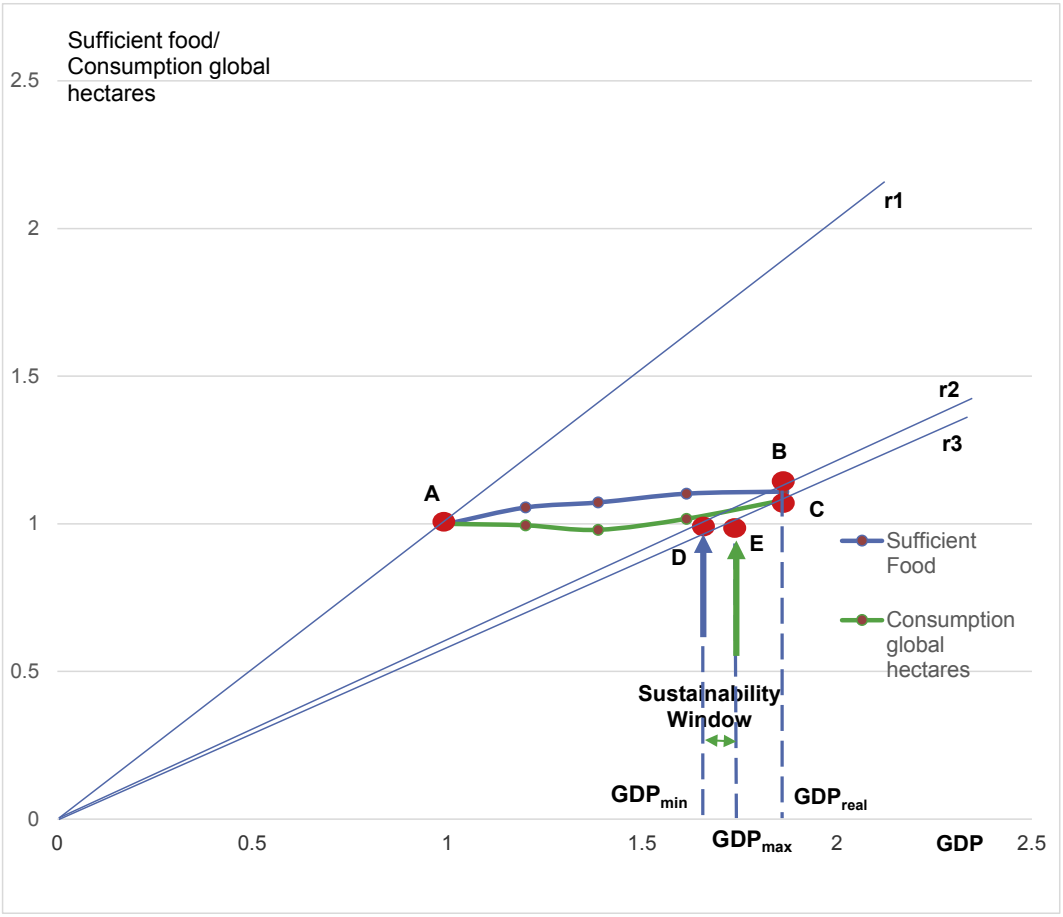

Fig. 3. Strong Sustainability Window for Lao PDR using 'Food sufficiency' as social indicator, 'Consumption of global hectares' as the environmental indicator, and GDP as the economic indicator for the analysis of sustainability.

the productivity has decreased in relation to these indicators (slopes of r2 and r3 are smaller than the slope of r1). Point D describes the minimum economic development along line r2 to result a non-decreasing welfare development (Healthy Life Years should not decrease). In this point the value for Healthy Life Years would be equal to the base year value (=1). This determines the minimum level of economic development with the productivity determined by r2 where the Healthy life Years would not decrease. This is the lower limit for the Sustainability Window, GDP_{min}. With the productivity determined by r2 the GDP should be higher than GDP_{min} in order not to decrease Healthy Life Years compared to the base year situation.

The maximum level of economic growth is determined by the environmental criterion. In this case the Weak Sustainability criterion is that the GHG emission intensity should not increase. The line r3 determines the productivity of greenhouse gas intensity in 2014 and defines the maximum sustainable GDP growth to be at point E, which determines GDP_{max}. At the level GDP_{max} the GHG intensity is not higher than the base year intensity.

GDP_{min} and GDP_{max} determine the Sustainability Window indicated with the green arrow in Fig. 1. Using these indicators the real GDP growth (GDP_{real}) in Lao PDR is between GDP_{min} and GDP_{max} indicating that the Lao development fulfils the Weak Sustainability criterion.

The Sustainability Window can be calculated using following equations:

$$SW_{low_{t0-t1}} = \frac{\frac{econ_{t1}}{econ_{t0}}}{\frac{well_{t1}}{well_{t0}}} \quad (1)$$

$$SW_{high_{t0-t1}} = \frac{\frac{econ_{t1}}{econ_{t0}}}{\frac{env_{t1}}{env_{t0}}} \quad (2)$$

where

$SW_{low_{t0-t1}}$ is the lower limit of economic level (GDP_{min}),
$SW_{high_{t0-t1}}$ is the higher limit of economic level (GDP_{max}),
$econ_{t0}$ is the economic indicator at the base year,
$econ_{t1}$ is the economic indicator at the final year,
$well_{t0}$ is the welfare (social) indicator at the base year,
$well_{t1}$ is the welfare (social) indicator at the final year,
env_{t0} is the environmental indicator at the base year,
env_{t1} is the environmental indicator at the final year.

The changes in Sustainability Window as a function of time can be analysed using the same method. The dynamic behaviour of the Sustainability Window in the case of Fig. 1 is presented in Fig. 2, where the GDP_{min} and GDP_{max} are shown together with the real GDP growth for the different years where data was available.

4. SuWi analysis and results

The results of the Sustainability Window analysis of Lao PDR are presented with the following graphs. For the analysis we have

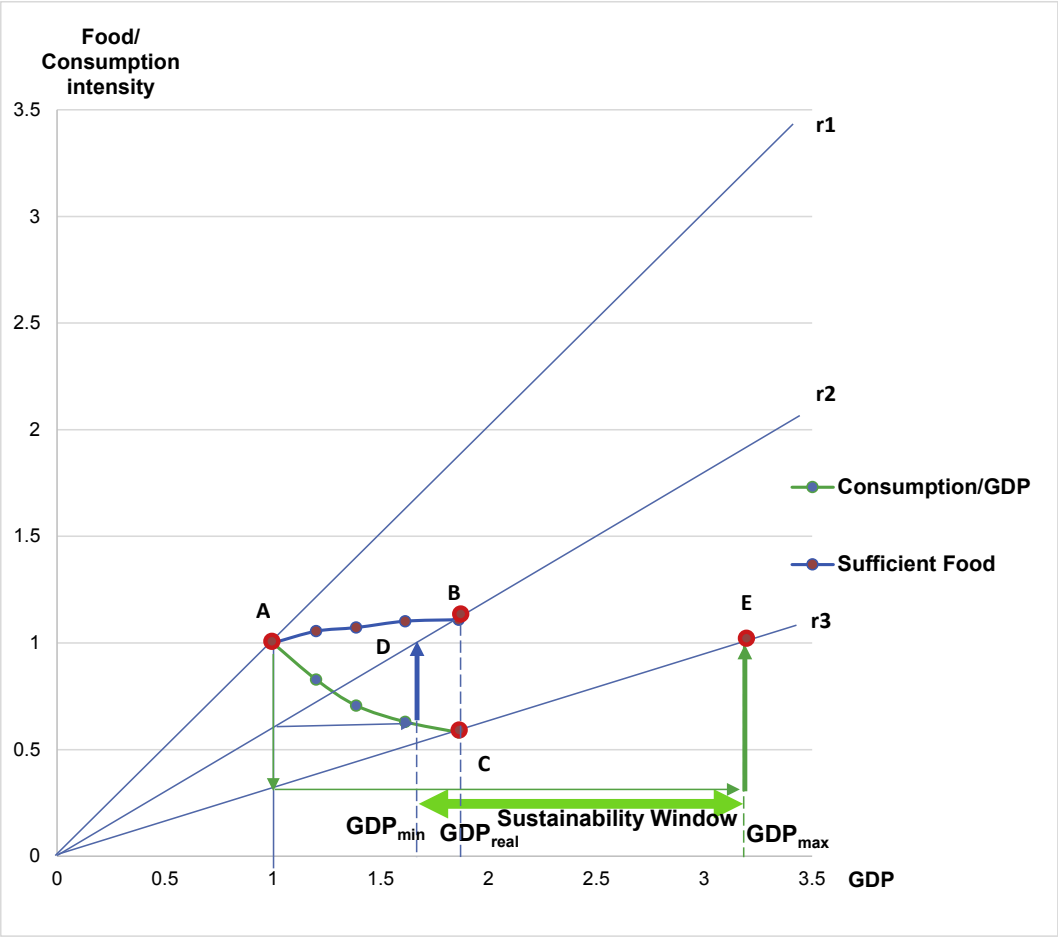

Fig. 4. Weak Sustainability Window for Lao PDR using 'Food sufficiency' as social indicator, 'Consumption intensity of global hectares' as the environmental indicator, and GDP as the economic indicator for the analysis of sustainability.

selected different indicators to elucidate the use of the analysis tool, and to illustrate the differences related to the use of different indicators and the weak and strong sustainability.

Fig. 3 shows an example of Sustainability Window for Lao PDR using 'Food sufficiency' as the social indicator, 'Consumption of global hectares' as the environmental indicator, and GDP as the economic indicator. In this case the 'Food sufficiency' productivity line r2 determines the minimum economic growth to be at the level of D (GDP_{min}). The productivity line for 'Consumption of global hectares' r3 determines the maximum GDP growth to be at the level of E (GDP_{max}). The minimum and maximum GDP levels determine the Strong Sustainability Window (green arrow in the Fig. 2) and we find out that the real GDP level is higher than GDP_{max}. In this case the Lao development does not fulfil the Strong Sustainability criteria.

In Fig. 3 we have carried out the analysis of Weak Sustainability using the same indicators as in Fig. 2, but using the intensity indicator 'Consumption intensity of global hectares' for the environmental dimension. In this case we can observe that development (GDP_{real}) is within the Weak Sustainability Window in Lao PDR (see Fig. 3).

In this case the lines r2 and r3 determine that the sustainable economic growth should be between points D and E (GDP_{min} and GDP_{max}). The real growth is between these limits indicating that development in Lao PDR fulfils the Strong Sustainability criteria measured with these indicators (see Fig. 4).

Fig. 5 visualises the Sustainability Window for Lao PDR using 'Social inclusion' as the social indicator, 'Unsafe sanitation' as the environmental indicator, and GDP as the economic indicator for the analysis of sustainability. A Strong Sustainability Window can be identified in the case of Sanitation indicator in the Lao PDR. Fig. 6 shows analysis for Weak Sustainability Window for Lao PDR using 'Social inclusion' as the social indicator, 'Greenhouse gas emission intensity' as the environmental indicator, and GDP as the economic indicator for the analysis of sustainability. Using these indicators the real GDP growth appears to be within the Sustainability Window, indicating that the development fulfils the Weak Sustainability criteria.

A compilation of the results indicating whether the real GDP development is within the Sustainability Window is presented in Appendix 2, for the different possible combinations of the social indicators, and three environmental indicators used in the above case examples. The results are shown for the cases of strong sustainability (absolute changes in environmental indicators) and weak sustainability (intensity changes of environmental indicators, indicator/GDP). The Sustainability Window analysis can also be used for the assessment of the Efficiency or Productivity Gap. The analysis is shown in Fig. 7 using 'GHG emissions' as the environmental indicator, 'Healthy Life Years' as the social indicator, and GDP as the economic indicator.

The Strong Sustainability Window analysis reveals that minimum sustainable growth (GDP_{min}) determined by 'Healthy Life Years' and line r2, is much higher than the maximum sustainable growth (GDP_{max}) determined by 'Greenhouse gas emissions' and

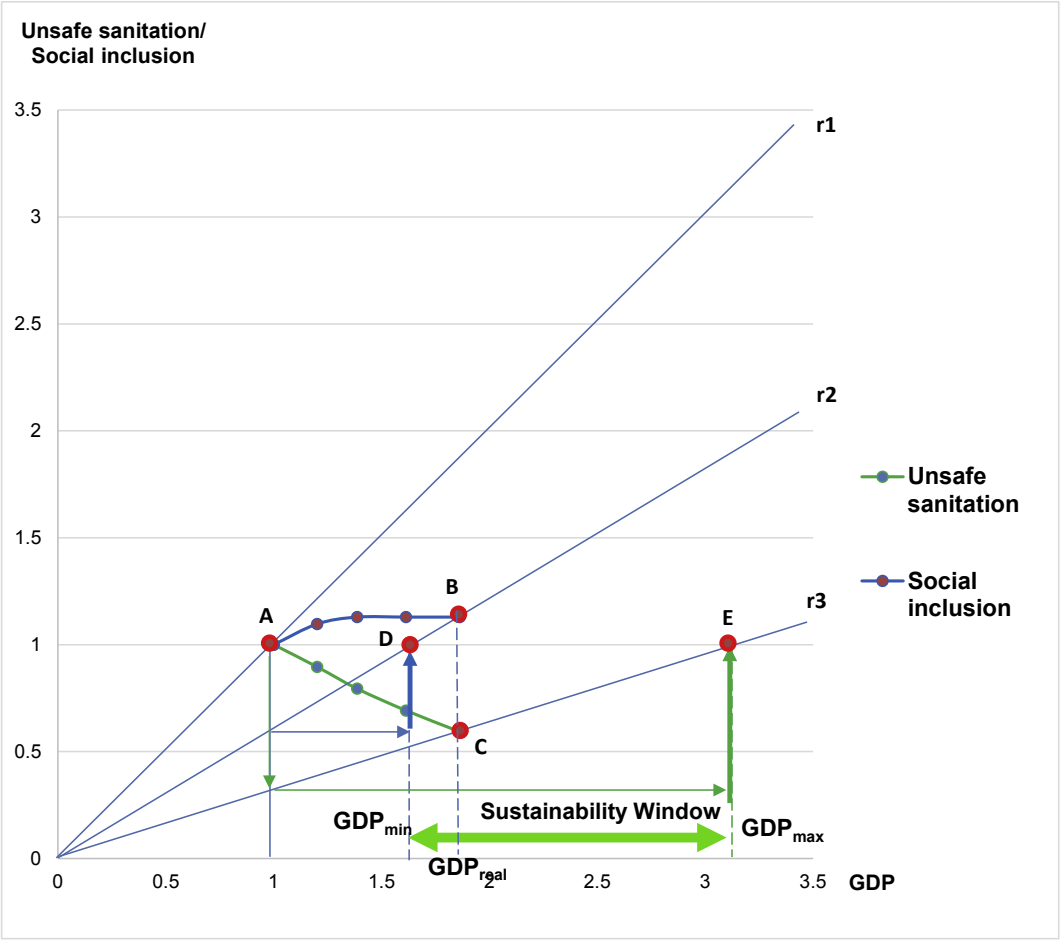

Fig. 5. Strong Sustainability Window for Lao PDR using 'Social inclusion' as social indicator, 'Unsafe sanitation' as the environmental indicator, and GDP as the economic indicator for the analysis of sustainability.

line r3. This means that there is an Efficiency Gap to fulfil the Strong Sustainability criteria. Instead of the actual GHG productivity line r3 (leading to emission level C in the final year 2014), strong sustainability would require we an efficiency improvement as shown by productivity line r4. This would lead to emission level F during the final year equalling the base year emission level A.

The Efficiency Gap can be calculated as

$$EG_{t1-t0} = \frac{env_{t1}}{econ_{t1}} - \frac{env_{t0}}{econ_{t1}} = \frac{env_{t1} - env_{t0}}{econ_{t1}} \quad (3)$$

where

$EG_{t1\text{-}t0}$ is the Efficiency Gap for year final year compared with the base year,
env_{t1} is the environmental indicator at the final year,
env_{t0} is the environmental indicator at the base year,
$econ_{t1}$ is the economic indicator at the final year,
$econ_{t0}$ is the economic indicator at the base year.

5. Discussion

The United Nations has announced 17 Sustainable Development Goals to be reached by 2030, with 169 associated targets, that are integrated and indivisible (UN, 2015). The SuWi methods presented in this article can be used in the regional and national evaluations of sustainable transition processes in all countries where sufficient data is available. From this global perspective these new analysis tools can be useful for local, national, regional and global decision makers to detect key aspects of sustainable transition path (either weak or strong sustainable development path). The analysis indicates the synergies and linkages between indicators and addresses gaps and weak points in current trends related to economic, environmental and societal development. For a comprehensive understanding, in further analyses it is important to use effective SuWi algorithms to present larger coverage of sustainability transition analyses. In this study we have demonstrated some policy-relevant analyses for Lao PDR, whereas in previous studies we have demonstrated the use of these tools for China (Luukkanen et al., 2015). The SuWi approach can also be utilized for nexus analyses. Poverty-environment nexus analysis of Lao PDR (Pasanen et al., 2017) can provide a good basis for SuWi analysis. In addition, SuWi analysis can be used as a foundation for backcasting scenario analyses.

In this article we have presented various Sustainability Window analyses, which are linked to the key issues of the green growth strategy of Lao PDR supported by the World Bank (World Bank, 2016b). The analyses cover the three pillars of Green Economy; (i) low carbon development, (ii) resource efficiency and (iii) social inclusion. The Sustainable Society Index (SSI) database provides useful indicators for the sustainability analysis, while this article demonstrates the ways in which the indicators can be utilized in

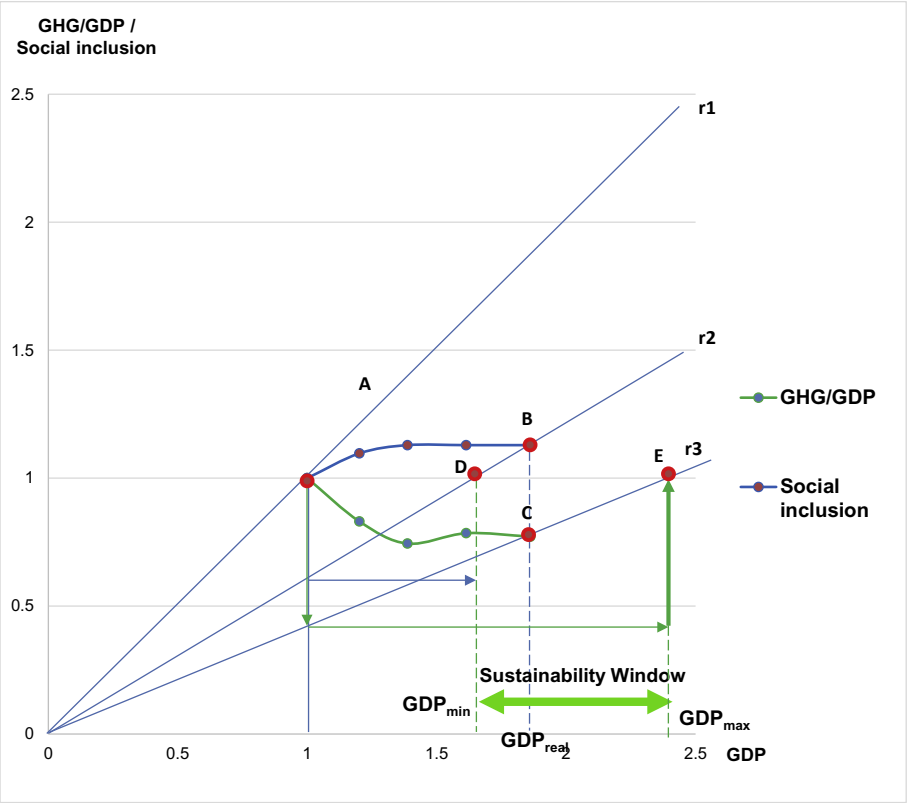

Fig. 6. Weak Sustainability Window for Lao PDR using 'Social inclusion' as the social indicator, 'Greenhouse gas emission intensity' as the environmental indicator, and GDP as the economic indicator for the analysis of sustainability.

the Sustainability Window framework, for integration of the different dimensions of development. The use of additional World Bank indicators widens the perspective of the analysis.

The analysis tool that we are presenting provides novel possibilities to include the different dimensions of sustainability in a single integrated framework. One of the key benefits of such a tool is the user-friendliness of the comparison of different variables and their outcomes. It also provides a basis for more comprehensive analysis, especially where new indicators and datasets such as the Sustainable Society Index (SSI) are available. The results obtained with the SuWi naturally depend on the indicators used, and indicator quality is an important analyst consideration. Similarly, the broader the scale of parameters, the more comprehensive the results.

The novel Efficiency Gap analysis provides new information on the improvement needed in the efficiency of different production processes. In this article we have used the Efficiency Gap for the analysis of the improvement required in the GHG intensity of GDP. The Efficiency Gap analysis can be used for analysis of any environment-related development when suitable indicators are available. The Efficiency Gap analysis provides necessary information for planners and policy makers in sectors where policy intervention is required to pursue a greener economy.

Aggregate national level indicators do not provide information of local level development, but do present a view of the general development trends in society. It is crucial to keep this in mind when interpreting the results, as localised and non-quantifiable issues are not represented, a common issue with quantitative data analysis. There can be notable variations between regions with regard to; income or gender equity, natural resources and their use, poverty rates, conflicts, cultural factors to social development, and other priority social and political issues, and national-level analysis do not take these factors into account. Thus, the aggregation and scaling of spatial sustainability analyses must be planned carefully for optimal results.

In addition, the qualitative aspects of development are not easily integrated into the quantitative indicators applied even though the indicators cover several aspects of development (Krank et al., 2013). This is a known limitation of all quantitative approaches to analysing development. Further, secondary data in the SSI is are derived from various multinational and nongovernmental organisations, and possible gaps in data are not identified. In 2012, the Joint Research Centre of the EU reported: "However, it [the SSI] can be used to simulate the consequences of a range of potential actions, providing a powerful tool to inform decisions about how to achieve human and economic growth without compromising the environmental wellbeing". (Joint Research Centre, 2012, p. 51). This observation, and related database corrections since 2012, will limit the extent of data gaps.

For a developing country such as Lao PDR, it is a challenge to further enhance and extend policy for sustainable development, and to set up implementation plans for the various sectors in an interlinked and holistic manner. Lao PDR has already mainstreamed sustainability and the Green Inclusive Economy into sectoral and national policy documents (Lao PDR, 2015 &2016), within which provisions include implementation plans and monitoring frameworks. However, tracking this development may turn out to be a challenging task, with Lao Statistics Bureau lacking information on 40% of Sustainable Development Goal indicators (Lao PDR, 2017). In this respect, the SSI data-base and the SuWi Analysis can provide analysis only to a certain extent on the actual level of sustainability of growth. Furthermore, SuWi itself does not provide

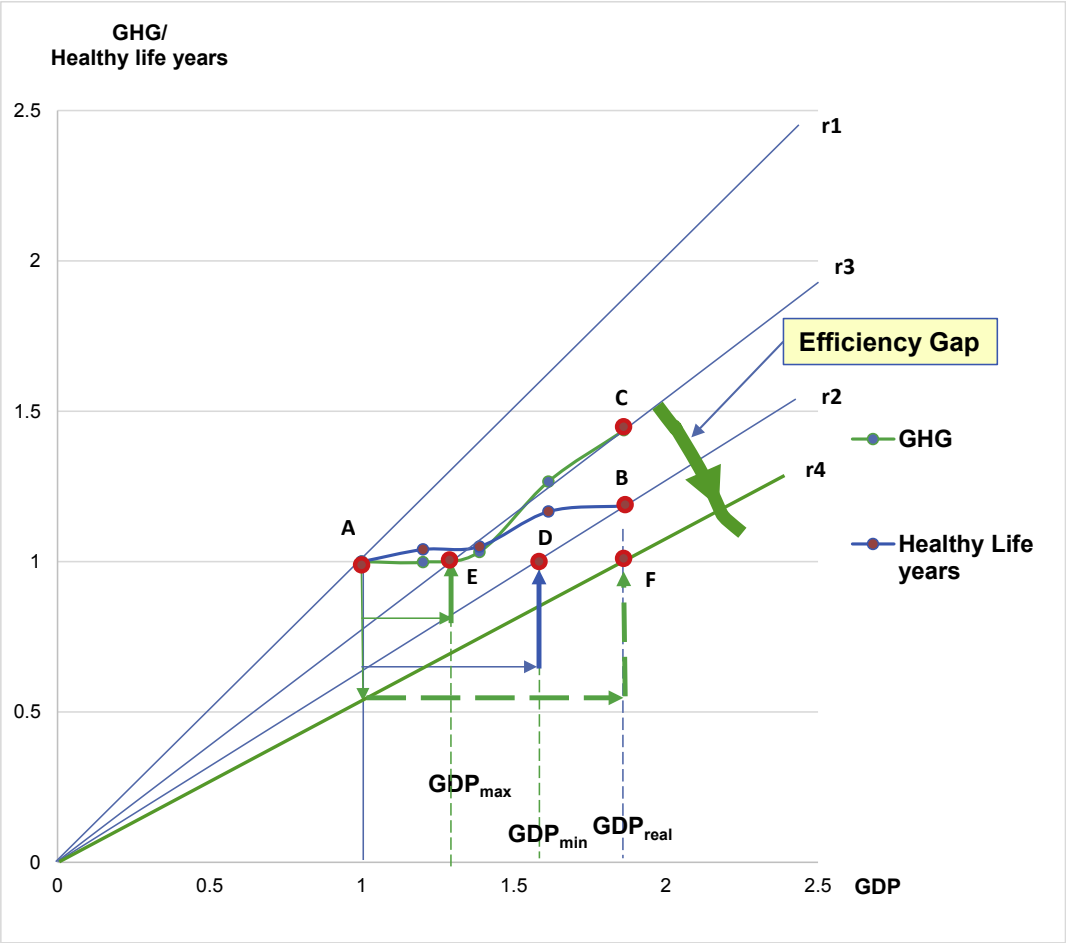

Fig. 7. Efficiency Gap analysis using Strong Sustainability Window analysis for Lao PDR; using 'GHG emissions' as the environmental indicator, 'Healthy Life Years' as the social indicator, and GDP as the economic indicator.

any policy recommendations but can be used to point out interlinkages such as those between economic growth, social inclusion and low carbon development. These in turn can provide useful information for policy makers, and highlight areas where more efforts are needed for inclusive and environmentally sound development. SuWi contributes to understanding development pathways in the recent past and can assist in making informed decisions for the future. Hence, SuWi can supplement anticipation and foresight activities. Reflexive governance for sustainable development necessitates such flexible planning methods.

This SuWi analysis for Lao PDR underlines that achieving strong sustainability while pursuing economic development is not straightforward. In practical terms the analysis aids Lao decision makers in matters related to the recent plans of revamping of the transport sector. There is a height of possibilities to guide energy sector development in a path that does not increase GHG emissions, requiring decarbonisation of the transport sector and a decision not to build any new fossil (lignite) based power production. To support transport decarbonisation there are two key options: (i) to increase the share of biofuels, and/or (ii) commence electrification of the transport sector. The electrification of transport could provide additional benefits such as reduction of the import costs of gasoline and diesel, and also lower pollution levels in cities. The allocation of new investments in green technology options, energy efficiency and R&D, can be the main policy tool to guide future development in Lao PDR towards a more sustainable direction.

SuWi Analysis can benefit LDC countries in the future due to the flexibility in using different types of indicators as explained in section 3. Such future analysis could include the use of SDG or other sustainability indicators, to track synergies and complementarities or possible competing priorities in trade-offs.

6. Conclusions

According to the Sustainability Window analyses carried out in this explorative case study, a number of core conclusions can be drawn:

- Lao PDR development fulfils the Weak Sustainability criterion according to (1) GDP growth indicator, (2) GHG intensity as the environmental indicator, and (3) Healthy Life Years as the social indicator (see Figs. 1 and 2).
- With the indicators (1) GDP growth, (2) Food sufficiency as the environmental indicator and (3) Consumption of global hectares as the social indicator, the Lao PDR development fulfils the Weak Sustainability criteria (see Fig. 3).
- With the indicators (1) GDP growth, (2) Food sufficiency as the environmental indicator and (3) Consumption intensity as the social indicator, the Lao PDR development fulfils the Strong Sustainability criteria measured with these indicators see (Fig. 4)

- With the indicators (1) GDP growth, (2) Unsafe sanitation as the environmental indicator and (3) Social inclusion as the social indicator the Lao PDR development fulfils the Strong Sustainability criteria (see Fig. 5).
- With the indicators (1) GDP growth, (2) Greenhouse gas emission intensity and (3) Social inclusion as the social indicator the Lao PDR development fulfils the Weak Sustainability criteria (see Fig. 6).
- In addition, a Sustainability Window analysis is implemented for the assessment of the Efficiency or Productivity Gap to stronger sustainability. This demonstration was presented in Fig. 7 using GHG emissions as the environmental indicator, Healthy Life Years as the social indicator, and GDP as the economic indicator. The key result of this demonstration is that Lao PDR should eliminate existing productivity gap problems in the field of GHG emissions to reach a strong sustainable development path in this special strategic sustainability field.

In general, we can conclude that water and sanitation problems have been managed in a more sustainable way than energy and GHG emission problems, when evaluating sustainable development policy from the Sustainability Window perspectives. In most cases we found a weak sustainability window, and only one strong sustainability window. Our SuWi analysis supports a conclusion that there is strong sustainability the area of sanitation.

A great challenge to holistic sustainability in Lao PDR and elsewhere is to examine the range of plausible future pathways of combined social, economic, environmental, technical, cultural and political systems under conditions of uncertainty, surprise, human choice and complexity. This requires charting new scientific territory and expanding the current global change research agenda and developing new tools and methods for transdisciplinary sustainability science. Transdisciplinary research of sustainable development also requires the use of mixed methods and understanding the nature of complexity in a fundamental manner. The SuWi tool contributes to understanding the strong and weak sustainability alternatives in potential transition paths. It can support decision makers and planners by establishing coherent multidimensional analysis and inform about the necessities of fundamentally sustainable development pathways, acknowledging the multiple aspects of a functional society.

Acknowledgements

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Appendix 1

Table 1
Indexed data of the indicators of SSI database used in the SuWi analysis.

	2006	2008	2010	2012	2014
Healthy Life Years	1	1.04	1.05	1.17	1.19
GHG emissions	1	1.00	1.03	1.27	1.44
GDP	1	1.20	1.39	1.61	1.86
GHG/GDP	1	0.83	0.74	0.78	0.77
Unsafe sanitation	1	0.90	0.79	0.69	0.59
Sufficient Food*	1	1.06	1.07	1.10	1.11
Consumption**	1	0.99	0.98	1.02	1.08
Consumption/GDP	1	0.83	0.71	0.63	0.58
Social inclusion***	1	1.10	1.13	1.13	1.13

* % nourished
** global hectares
*** CPIA policies for social inclusion/equity cluster average (1 = low to 6 = high)

Appendix 2

Compaction of the results of the Sustainability Window analysis for Laos. The real GDP development for 2006–2014 is compared to the maximum and minimum levels of economic development in order to assess the sustainability in regard to eight different social indicators and four different environmental indicators. The strong sustainability criterion refers to the changes in absolute values of the environmental indicators and the weak sustainability criterion refers to the intensity value (indicator/GDP) of the environmental indicators. The table shows whether the real GDP level is within the Sustainability Window (Yes, $SW_{min} < GDP_{real} < SW_{max}$) or outside of it (No, $SW_{min} > GDP_{real}$ or $GDP_{real} > SW_{max}$).

	GHG		Consumption		Energy		Sanitation	
	Strong	Weak	Strong	Weak	Strong	Weak	Strong	Weak
Sufficent food	No	Yes	No	Yes	No	Yes	Yes	Yes
Healthy life years	No	Yes	No	Yes	No	Yes	Yes	Yes
Social inclusion	No	Yes	No	Yes	No	Yes	Yes	Yes
Sufficient drink	No	Yes	No	Yes	No	Yes	Yes	Yes
Gender equity	No	Yes	No	Yes	No	Yes	Yes	Yes
Income distribution	No	Yes	No	Yes	No	Yes	Yes	Yes
Good governance	No	No	No	No	No	No	No	Yes
Education	No	Yes	No	Yes	No	Yes	Yes	Yes

Green economic development in Lao PDR: Sustainability Window analysis of Green Growth Productivity and the Efficiency Gap.

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