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Sustainability Window (SuWi) Method For Doughnut Economy Model Construction. Assessment of Development in China, India, USA and Finland

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ABSTRACT

Sustainability assessment methods need to include different dimensions in a coherent analysis and comprehensive view of the development. In the basic form, sustainable development can be seen to include three dimensions: environmental, social and economic. These can be further developed in different sub-dimensions depending on the need for analysis and available information.
Sustainability Window (SuWi) is a novel method developed for the analysis of the sustainability of economic growth. SuWi method provides, on the one hand, information about the maximum economic development not to exceed the environmental limit of sustainability and, on the other hand, information about the minimum economic development to fulfil social sustainability. These minimum and maximum economic development determine the Sustainability Window.
SuWi method results can be used for constructing the Doughnut Economy model where the outer limit of economic development is determined by the environmental constraint and the inner limit by the social development need. This quantitative model illustrates the sustainable operation area for society.
In this paper, we have calculated the SuWi results for China, India, the USA and Finland to illustrate the method and constructed the Doughnut Economy model for these countries based on the SuWi results.

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The results indicate that there are different problems of sustainability in the analysed countries and sustainability strategy should be constructed based on the various challenges that the countries have.

KEYWORDS:
sustainability; sustainable development; Sustainability Window (SuWi); Doughnut Economy;

1 INTRODUCTION

The definition of Sustainable Development is often taken from the publication 'Our Common Future' [1] published by the Brundtland Commission. In this definition, it is stated that "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs". This definition emphasizes the needs approach and the possibilities to fulfil social needs without causing harm to the environment which could prevent future generations to live a decent life.

It is not easy to measure sustainable development and several different ideas and concepts for the measurement are proposed. Sustainable Development Goals (SDGs), developed in the UN framework [2], is a comprehensive system to classify different dimensions of sustainability and to measure the performance of different countries. There are also several other indicator systems developed for the assessment of sustainable development [3], [4] [5], [6].

Sustainable development is many dimensional process which is difficult to compress into a few indicators. The dimensions of development are interlinked and impact each other and that is why a comprehensive analytical framework is needed to illustrate the character of development. This article proposes a framework called Sustainability Window (SuWi) to be used for analysing the sustainability of development simultaneously in different dimensions of development to get a holistic view of the development. Next, the results of SuWi analysis are organised in a form to construct a model for Doughnut Economy for easy visual interpretation of the results.

2 METHODOLOGY AND DATA

2.1 Data sources

The data for the analyses is collected from Sustainable Society Index [3] and United Nations Sustainable Development Goals [4]. The analyses utilize time series data and that is the reason why special attention is paid to the continuity of the time series and the similarity of the base data for indicator construction. The data for the analyses covers the years 2006-2016 where reliable data was available in the SSI database. A detailed explanation of the indicators can be found in [3].

2.2 Sustainability Window method

Sustainability Window (SuWi) is a method to determine the maximum economic development not to exceed the environmental limit in the production of environmental stress. The environmental limit can be determined to be relative to some previous year's value (for instance reduction of environmental stress from base years value) or an absolute target based on the ecological evaluation. The determination of the absolute target is often not based on scientific fact, like the carrying capacity of the ecosystem, but on a political decision where

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other aspects are also taken into account. The SuWi method can be used in both cases of the relative or absolute target.

Weak sustainability criterion means that the environmental stress intensity (environmental stress/GDP) should not increase, i.e. the development is sustainable if the environmental stress increases slowlier than the economic growth. The strong sustainability criterion means that environmental stress should not increase. In these analyses, we have used strong sustainability criteria.

Figure 1 illustrates the construction of the Sustainability Window. In this example, we use Greenhouse gas emissions as an indicator of the environmental dimension, Healthy Life Years as an indicator of the social dimension and GDP as an indicator of the economic dimensions. Indicators are indexed so that the base year value for each indicator is 1. The economic dimension of the development is expressed on the x-axis and environmental and social dimensions are on the y-axis. Point A shows the starting point in the base year and line r1 illustrates the environmental stress productivity of the economy as well as the social welfare productivity. Point B shows the value of the social indicator four years after the base year and line r2 the social welfare productivity which has decreased in this example. If the social sustainability criterion is that the social welfare should not decrease point C determines the minimum economic development if the welfare productivity remains at the level r2 (ceteris paribus). This GDP_{min} determines the minimum level of economic development.

The greenhouse gas emissions, in this example, are at point C in the fourth year and this determines the environmental stress productivity line r3. If the environmental sustainability criterion is that the environmental stress should not increase the line r3 determines the maximum economic development GDP_{max}, point E, not to exceed the environmental burden. The Sustainability Window is now determined by $GDP_{min} < SuWi < GDP_{max}$.

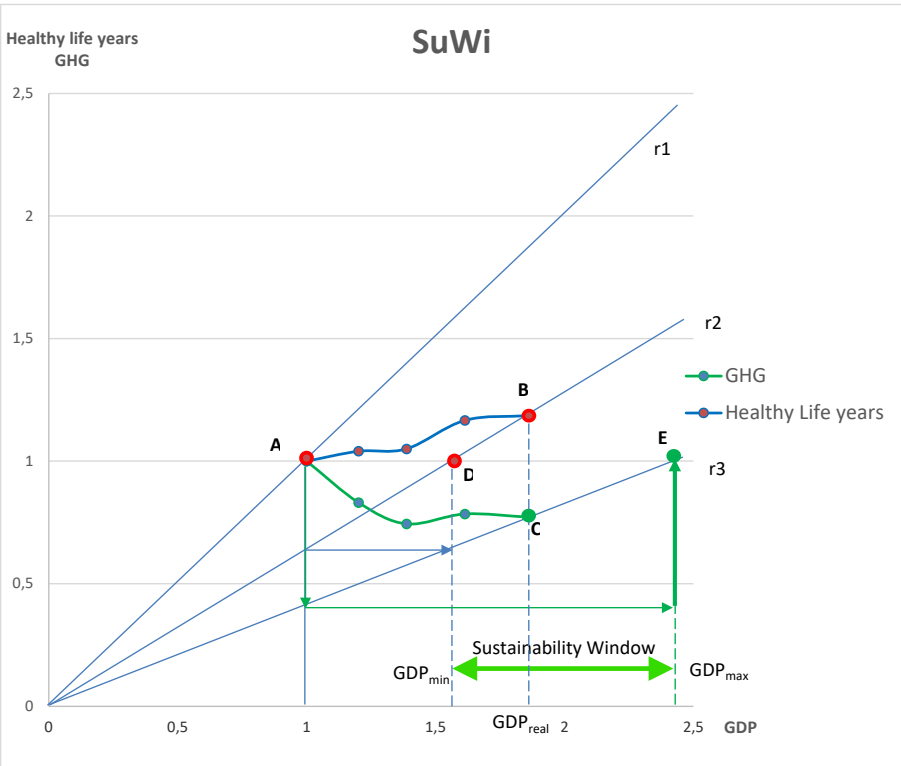

Figure 1. Determining the Sustainability Window with the development of social welfare (Healthy Life Years), environmental stress GHG emissions) and economic (GDP) indicators.

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If the real GDP growth is within the SuWi we can determine the development to be sustainable in relation to the used indicators. If $GDP_{min} > GDP_{max}$ the Sustainability Window does not exist. There are several possible combinations of SuWi depending on the values of the indicators (increasing or decreasing) and the changes in environmental stress and social welfare productivities. These are discussed in detail in [7].

This type of sustainability window can be constructed for different pairs of social and environmental indicators and it can be used to analyse also the trend of the changes for sustainability. The dynamic SuWi analysis [8] provides information on the development process and it can be used as a basis for scenario construction.

When the results of SuWi analyses are organized in a radial diagram we can construct the Doughnut Economy model. According to Kate Raworth [9] "The environmental ceiling consists of nine planetary boundaries, as set out by (Rockström et al., 2009), beyond which lie unacceptable environmental degradation and potential tipping points in Earth systems. The twelve dimensions of the social foundation are derived from internationally agreed minimum social standards, as identified by the world's governments in the Sustainable Development Goals in 2015. Between social and planetary boundaries lies an environmentally safe and socially just space in which humanity can thrive." The SuWi analysis provides quantitative information on these boundaries and the related economic development. The method provides a visual interpretation of the Doughnut and indicates where the problematic unsustainable development areas exist.

3 RESULTS

3.1 Doughnut Model

When the results of SuWi analyses are organized in a radial diagram we can construct the Doughnut Economy model. According to Doughnut Economy developer Kate Raworth [9] "The environmental ceiling consists of nine planetary boundaries, as set out by Rockström et al., [10], beyond which lie unacceptable environmental degradation and potential tipping points in Earth systems. The twelve dimensions of the social foundation are derived from internationally agreed minimum social standards, as identified by the world's governments in the Sustainable Development Goals in 2015. Between social and planetary boundaries lies an environmentally safe and socially just space in which humanity can thrive." The SuWi analysis provides quantitative information on these boundaries and the related economic development. The method provides a visual interpretation of the Doughnut and indicates where the problematic unsustainable development areas exist.

We have carried out analyses of the Doughnut Economy for China, India, the USA and Finland. The countries were selected for the analyses because they are crucial for global development both in the economic and environmental sense. Finland is added to the analysis because it illustrates a small open economy developed country with a good statistical basis. It has to be remembered that the comparison here is now based on relative changes from the base year 2006 value. The starting point for instance in per capita emissions of CO_2 is very different for the analysed countries; India 0.98 ton, China 4.6 ton, Finland 12.6 ton and the USA 18.8 ton per capita. It cannot be expected that India reduces the CO_2 emissions in the same way as the USA. If we assume that the general sustainable target for CO2 emissions in the world is about 1.8 tons per capita we can construct the following figures 2 and 3 to illustrate the required emissions reductions in India and the USA with indexed data.

Figure 2 shows the historical development part of emissions per capita and economic development in India from the year 2006 from point A to point B. If we assume CO2 emission intensity to remain at the same level as in the final year of analysis (ceteris paribus),

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illustrated with r2, the maximum economic development could reach GDP_{max} without exceeding the sustainability target of 1.8 tons per capita (point C).

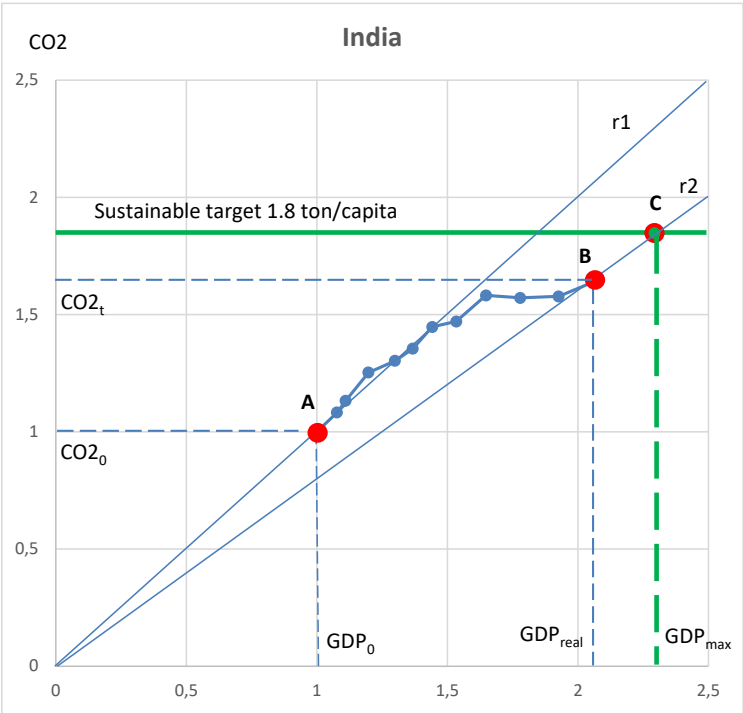

Figure 2. Analysis of the maximum level of economic growth in India if the sustainable target of CO2 emissions is 1.8 tons per capita. Point A refers to base year values of CO_2 emissions per capita and GDP and point B to last year's values. With the emission intensity r2 the maximum economic development is GDP_{max} not to exceed the sustainability target of emissions.

A similar analysis is carried out for the USA in Fig 3. Now the real GDP level in the final year of analysis is much too high to reach the sustainability target. The emissions intensity should be reduced considerably from the value r2 to the level of r3 or the economic growth should be reduced to the level of GDP_{maxr2} in order to reach the sustainable emission level.

Next the Doughnut Model analysis based on SuWi results will be presented. We have used the indicators shown in Table 1 for the analysis of the Doughnut Economy for China, India, the USA and Finland.

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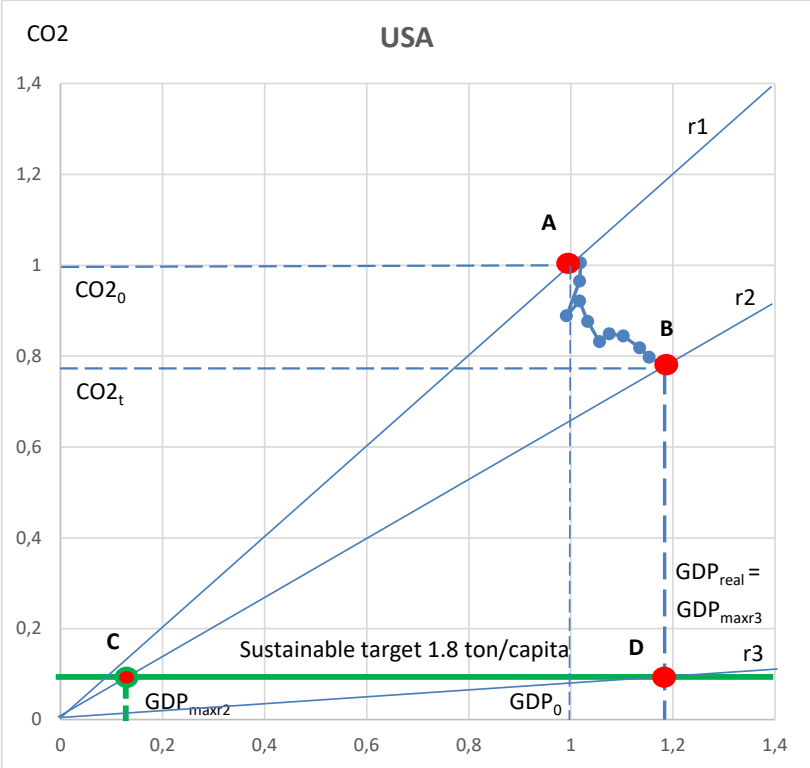

Figure 3. Analysis of the maximum level of economic growth in the USA if the sustainable target of CO2 emissions is 1.8 tons per capita. Point A refers to base year values of CO_2 emissions per capita and GDP and point B to last year's values. With the emission intensity r2 the maximum economic development is GDP_{maxr2} not to exceed the sustainability target of emissions. If the emission intensity can be reduced to the level r3 the maximum sustainable economic growth would be $GDP_{maxr3} = GDP_{real}$.

Table 1. Indicators used in the SuWi analysis and Doughnut Model for ASEAN countries.

Economic		**Environmental**		**Social**
GDP	Forest, For	Biodiversity, Forest area	Food	Sufficient food
	Conservation, Conse	Biodiversity, Protected area	Drink	Sufficient to drink
	Water	Renewable water resources	Edu	Education
	Consu	Consumption of global hectares	HLY	Healthy life years
	Intens	Energy intensity	Gend	Gender equality
	CO2	CO_2 emissions	Inc	Income distribution
	Ren energy	Renewable energy	Emp	Employment
	Organic	Organic farming	Soc inc	Social inclusion
	Sanitation	Safe sanitation	HDI	Human development

Figure 4 illustrates the results of SuWi analyses for China organized in the Doughnut Model form. The minimum and maximum values Sustainability Windows constructed for different pairs of social and environmental indicators are organized in a radial form to visualize the problematic areas of development. The maximum economic development in the case of different indicators, in relation to environmental development, is shown with the blue line. The minimum economic development, to guarantee sustainable social development, is

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indicated with the green line. The area between the blue line and green line, marked with green colour, forms the sustainable space for economic development, the Doughnut. Real economic development is indicated with the red line. The optimal situation would be if the red line would be on the green background because in that case, the development would be sustainable in relation to all the used indicators.

In the case of the Chinese development, the Doughnut Model indicates that the development of sanitation and energy intensity (savings) are well under control and fulfil environmental sustainability. Also, the use of renewable water is within sustainability limits.

The most problematic area in China is the CO_2 emissions and consumption of global hectares, which are clearly in an unsustainable state if strong sustainability criteria are used. Also, the biodiversity measured with forest area changes is in the non-sustainable area. Biodiversity measured with the amount of protected forest area organic farming are close to the limits of sustainability.

In the social development sphere, most of the indicators show sustainable development. The only problematic area here is the development of employment where real economic growth has not been able to keep up with the improvement of work efficiency reducing employment.

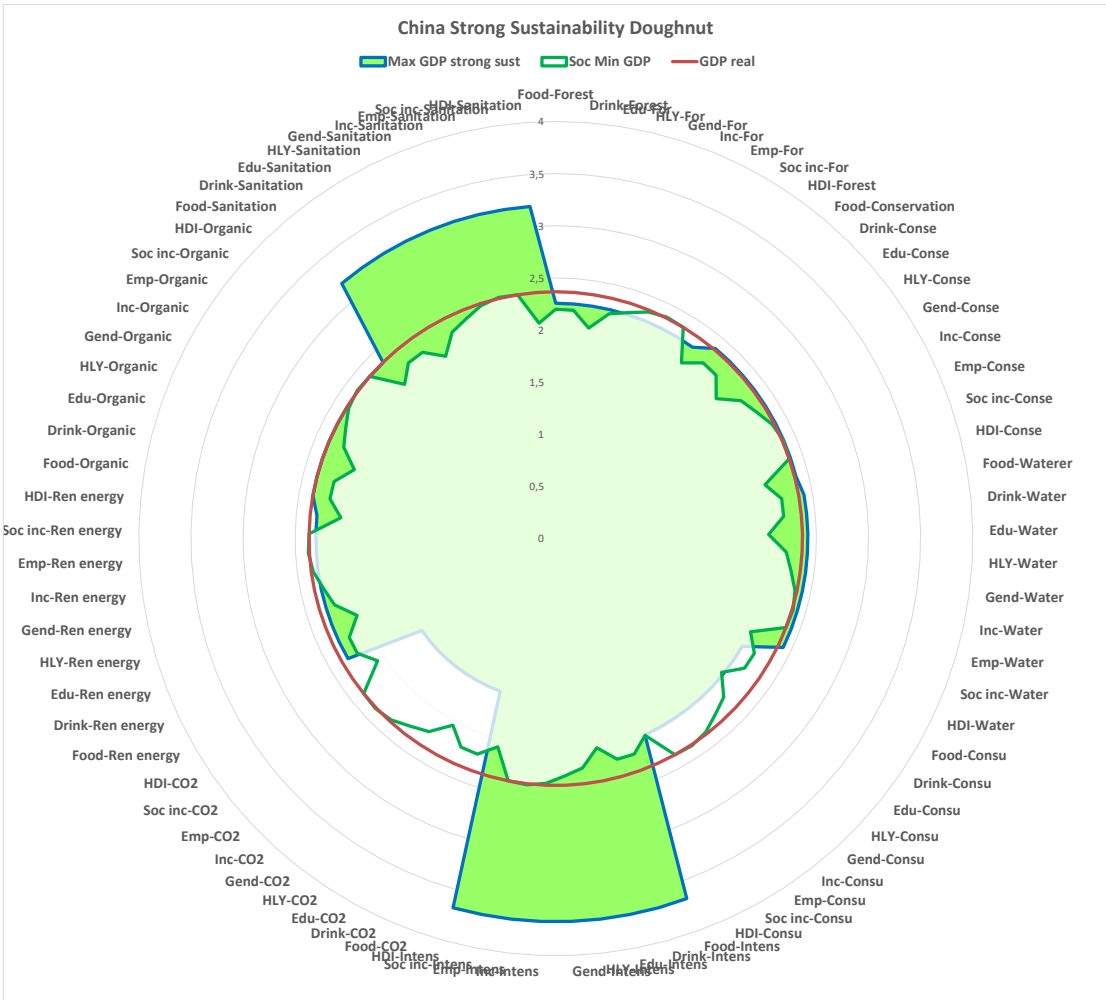

Figure 4. Doughnut Model for China for 2006-2016 using the indicators of Table 1.

A more detailed view of the maximum economic growth related to the environmental variables and the relation to real economic growth is shown in Fig 5. and the minimum

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economic growth related to social variables together with real economic growth is shown in Fig. 6.

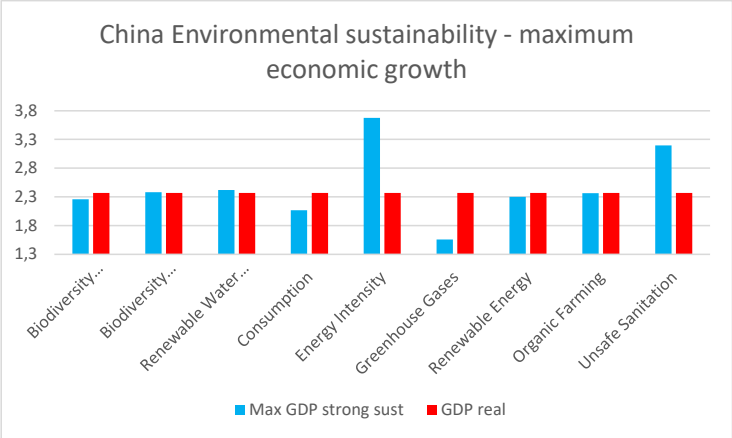

Figure 5. Maximum sustainable economic growth related to environmental limits (in Table 1) and real economic growth in China 2006-2016.

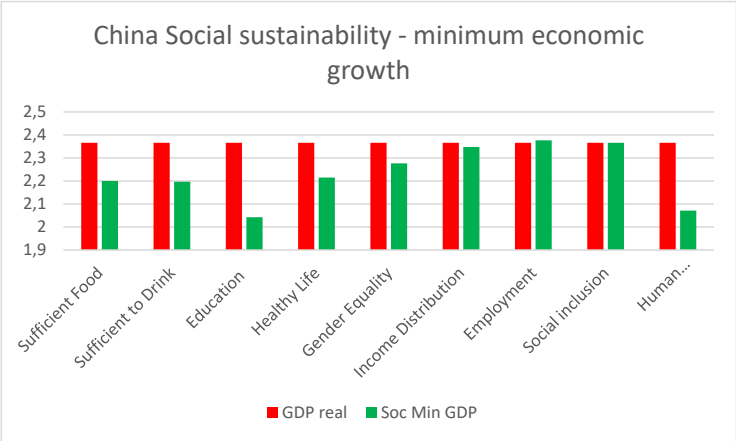

Figure 6. Minimum sustainable economic growth related to social limits (in Table 1) and real economic growth in China 2006-2016.

The doughnut Model for India is shown in Figure 7. India has performed well in relation to sanitation, energy intensity (savings), renewable water and forest conservation in the field of environmental sustainability. Also, consumption of global hectares, forest area and organic farming are within the sustainability limits. The most problematic area seems to be CO_2 emissions and renewable energy use.

In the field of social sustainability, India seems to be on the sustainability track related to several indicators; education, human development index, healthy life years, clean drinking water sufficiency, gender equality, food sufficiency and employment. Problematic areas seem to be income distribution and social inclusion.

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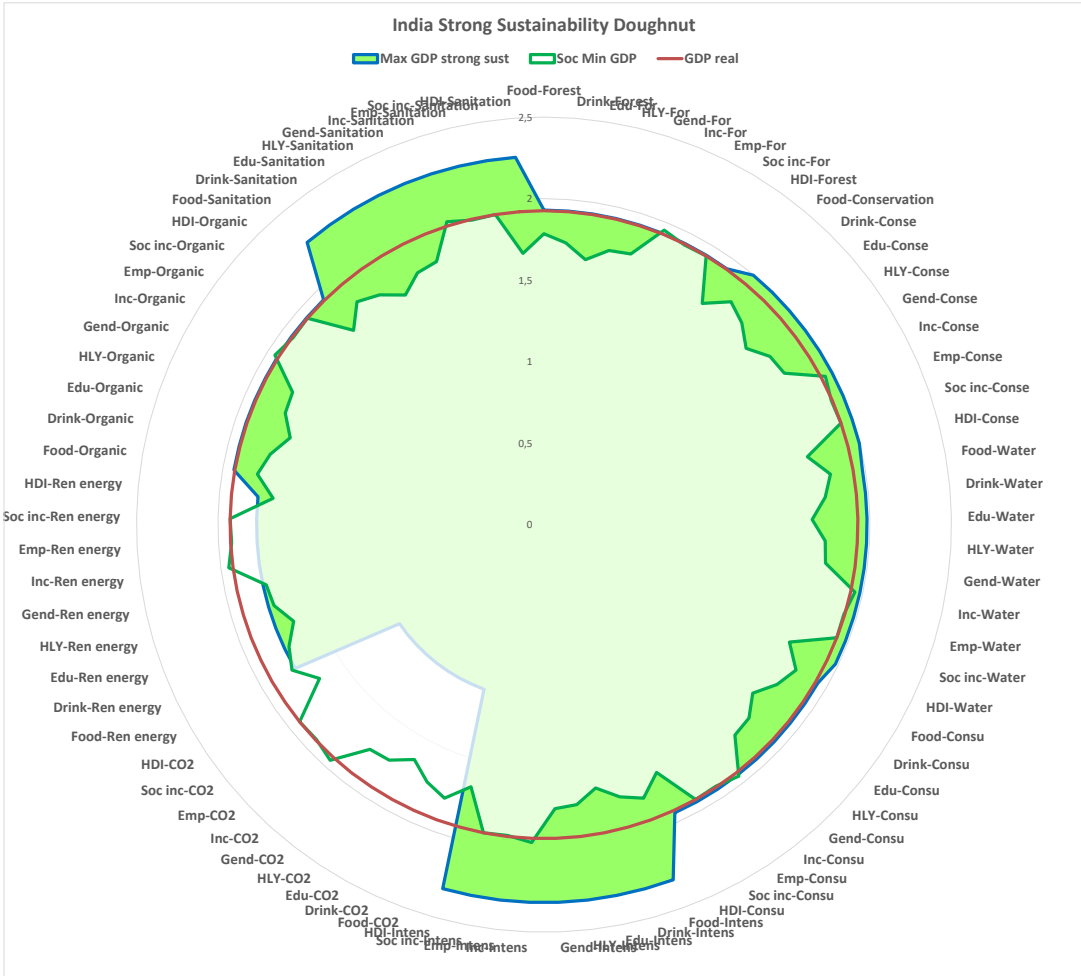

Figure 7. Doughnut Model for India for 2006-2016 using the indicators of Table 1.

A more detailed view of the maximum economic growth related to the environmental variables and the relation to real economic growth is shown in Fig 8. and the minimum economic growth related to social variables together with real economic growth is shown in Fig. 9.

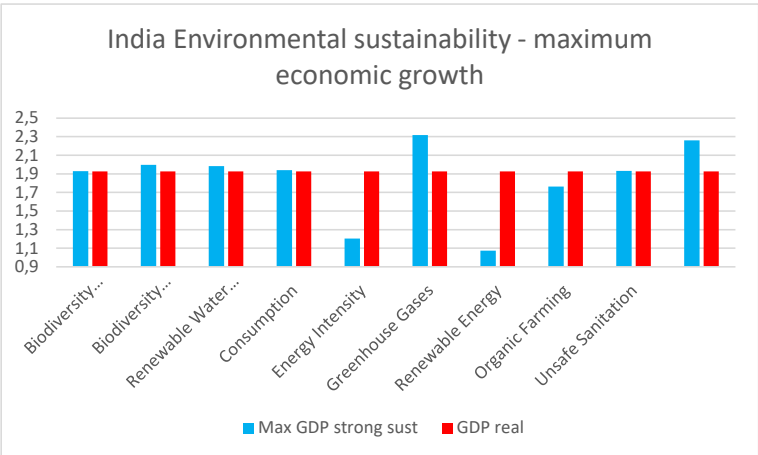

Figure 8. Maximum sustainable economic growth related to environmental limits (in Table 1) and real economic growth in India 2006-2016.

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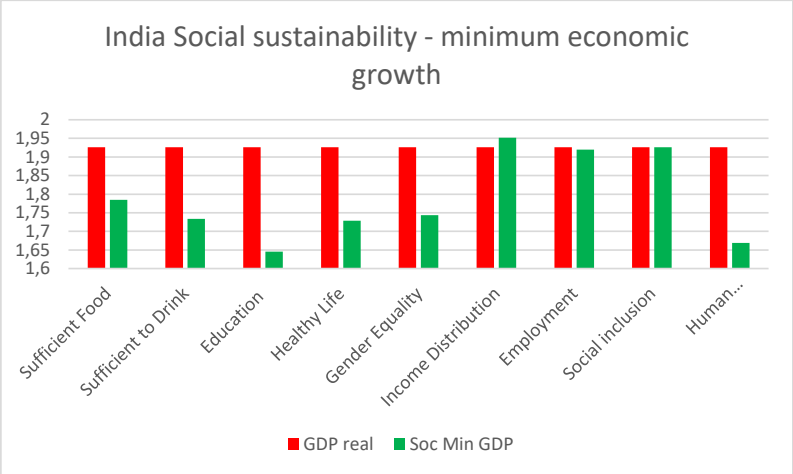

Figure 9. Minimum sustainable economic growth related to social limits (in Table 1) and real economic growth in India 2006-2016.

The strong sustainable Doughnut Model for the USA is presented in Figure 10. The USA has performed well in areas of reduction of energy intensity, CO_2 emissions, consumption of global hectares, conservation of forests and renewable energy use. Also, the forest area has slightly increased during the analysis period. Renewable water use as well as organic farming are problematic areas in the USA from the point of view of environmental sustainability when we look at changes from 2006 to 2016.

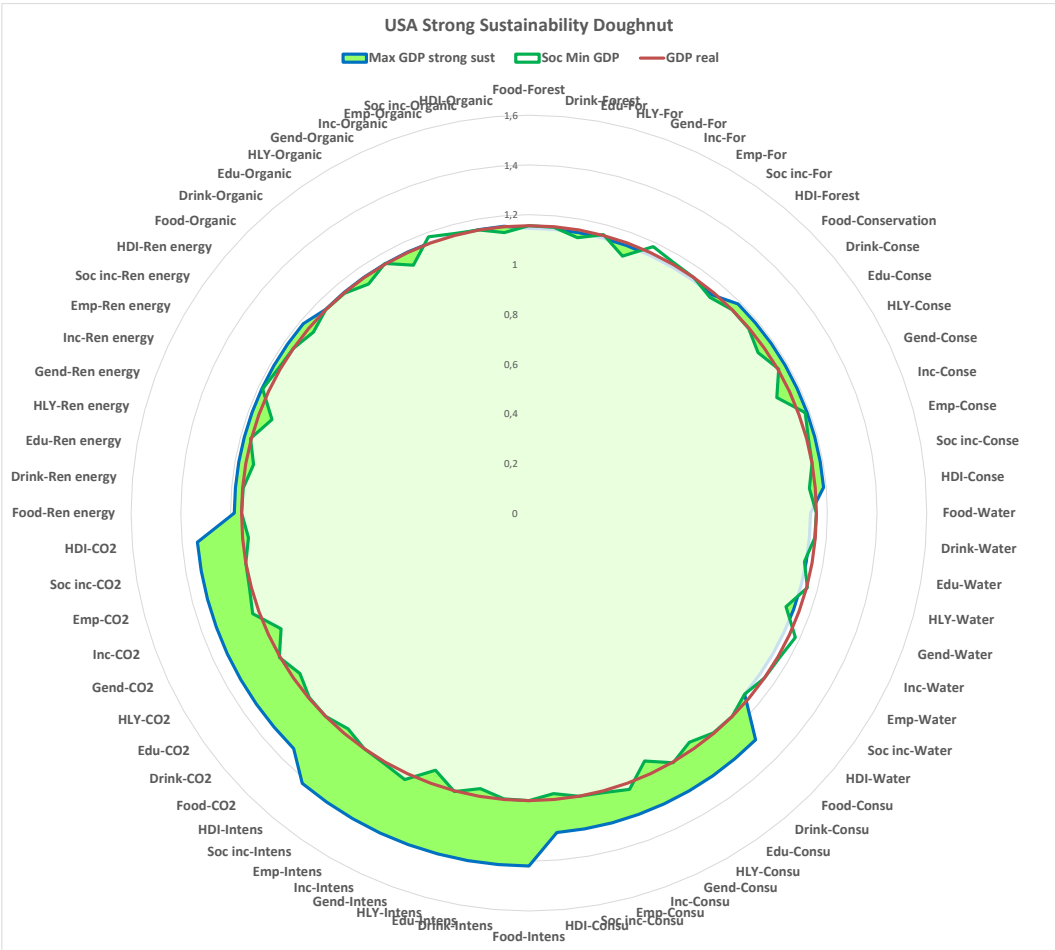

Figure 10. Doughnut Model for the USA for 2006-2016 using the indicators of Table 1.

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In the field of social sustainability, the USA has been successful in the areas of gender equality, education, the human development index and the sufficiency of clean drinking water. Problematic areas are income distribution, employment and healthy life years.

A more detailed view of the maximum economic growth related to the environmental variables and the relation to real economic growth is shown in Fig 11. and the minimum economic growth related to social variables together with real economic growth is shown in Fig. 12.

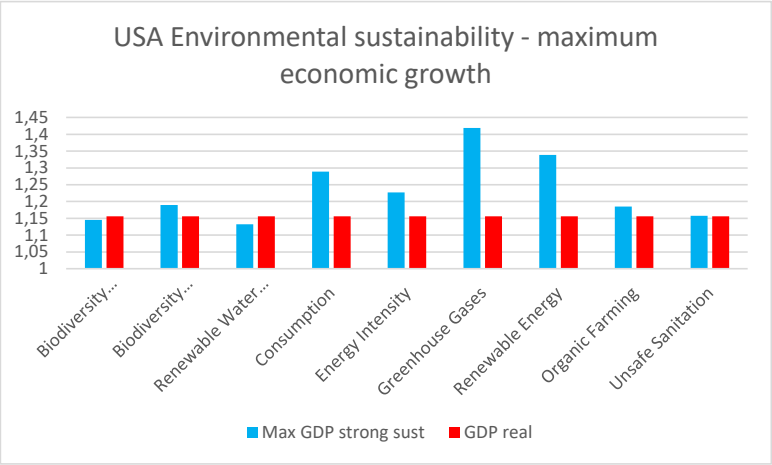

Figure 11. Maximum sustainable economic growth related to environmental limits (in Table 1) and real economic growth in the USA 2006-2016.

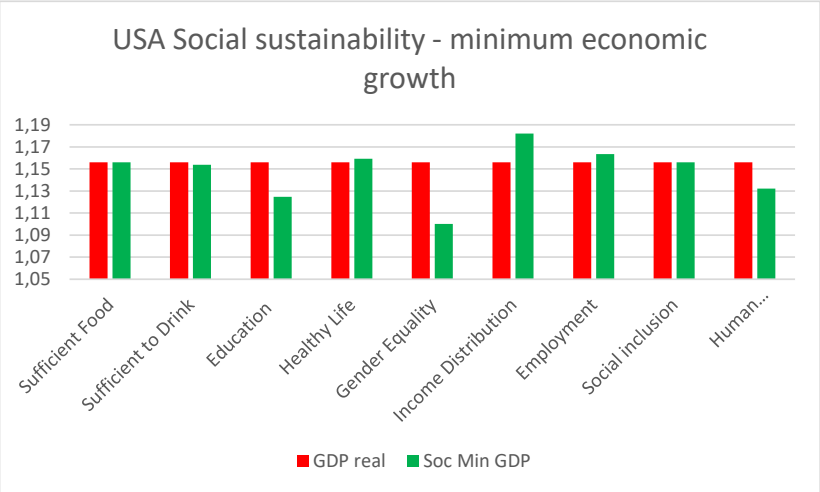

Figure 12. Minimum sustainable economic growth related to social limits (in Table 1) and real economic growth in the USA 2006-2016.

The Doughnut Model for Finland is presented in Figure 13. Finland has been successful in the reduction of CO_2 emissions, decreasing energy intensity, use of renewable energy, conservation of forests, renewable water use, organic farming and increase in the forest area. The problematic area in Finland is the consumption of global hectares which is related to the dependence and increase of foreign trade.

In the field of social sustainability, Finland has been successful in the areas of education, gender equality, the human development index and employment. Problematic areas are income distribution and healthy life years. Clean drinking water and food sufficiency have not been problematic in Finland.

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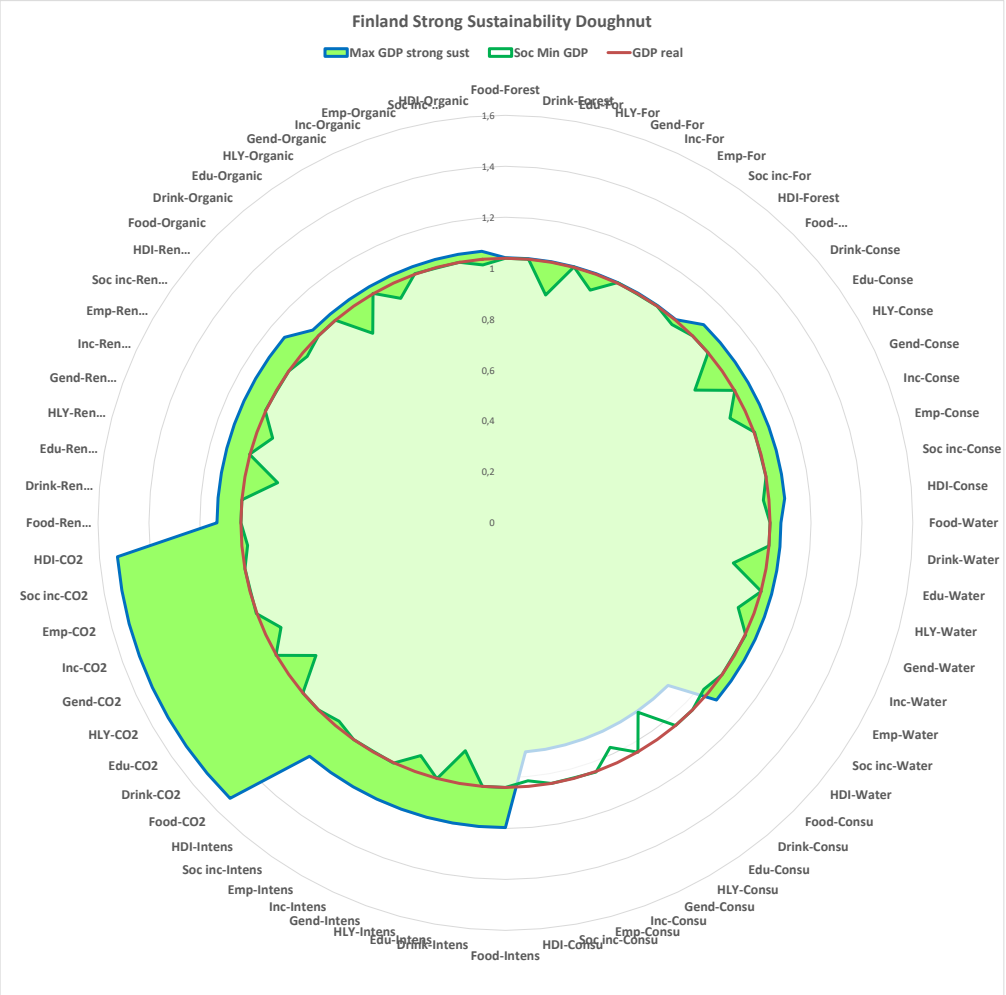

Figure 13. Doughnut Model for Finland for 2006-2016 using the indicators of Table 1.

A more detailed view of the maximum economic growth related to the environmental variables and the relation to real economic growth is shown in Fig 14. and the minimum economic growth related to social variables together with real economic growth is shown in Fig. 15.

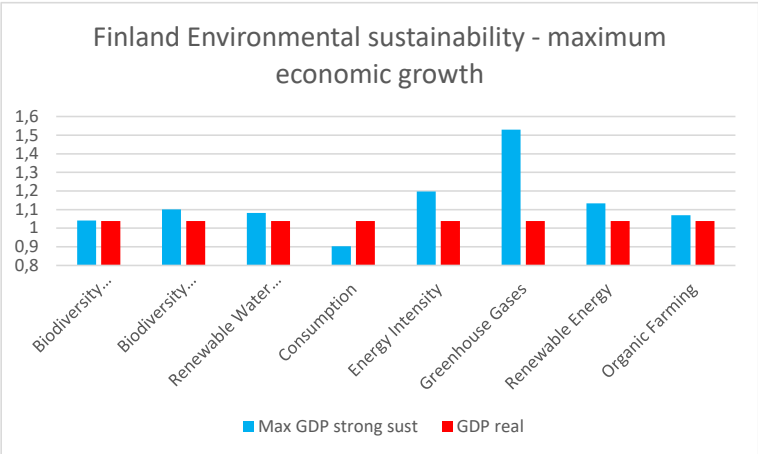

Figure 14. Maximum sustainable economic growth related to environmental limits (in Table 1) and real economic growth in Finland 2006-2016.

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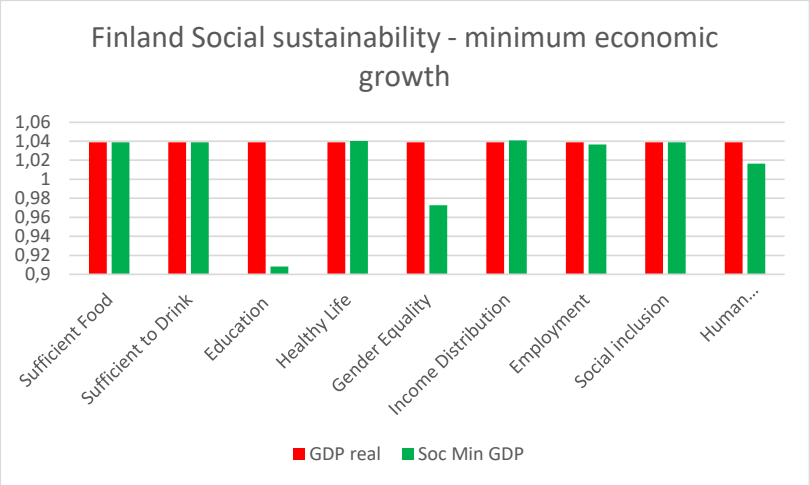

Figure 15. Minimum sustainable economic growth related to social limits (in Table 1) and real economic growth in Finland 2006-2016.

4 CONCLUSION

Sustainability Window (SuWi) method provides a novel tool for analysing sustainability simultaneously in the different dimensions, social, economic and environmental. It provides a firm basis for quantitative analysis of the development processes in these dimensions. The method makes it possible to use numerous different indicators for analysis of the development of different sectors and for looking at the interlinkages and synergies in the development. This can lead to more balanced policy planning. The method reveals the problematic areas related to sustainability and can be used for comparative analyses.

The SuWi method results can be used for Doughnut Model construction. The Doughnut models can be used for visualizing the sustainability results. It illustrated the area where sustainability targets are not met and further policy actions are needed. The SuWi method and Doughnut Model can provide important information for policy planning in an easily understandable form. They can be used as information tools for planning in different sectors of society and can communicate complex development problems.

The SuWi method can be used for trend analysis to provide important information on the directions of development processes. The trend analyses can be used as a basis for scenario construction and analysis of potential problematic development paths in different areas in the future. The results of dynamic SuWi analysis and scenario construction can be used for Doughnut Model construction for the future. This is important when policy planning is discussed with different stakeholder groups.

It is important to make a distinction between relative and absolute sustainability when the results of the SuWi method are discussed. The illustration of the difference between Indian and the USA's CO_2 emissions gives a concrete example of this. Climate policy has been geared towards the relative reduction of emissions from the base year level, but this omits the crucial point of the absolute levels of emissions. The SuWi method is well-equipped to use both relative and absolute targets for the analysis of sustainability. This is important when comparative analyses are carried out and the targets are set for sustainability.

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