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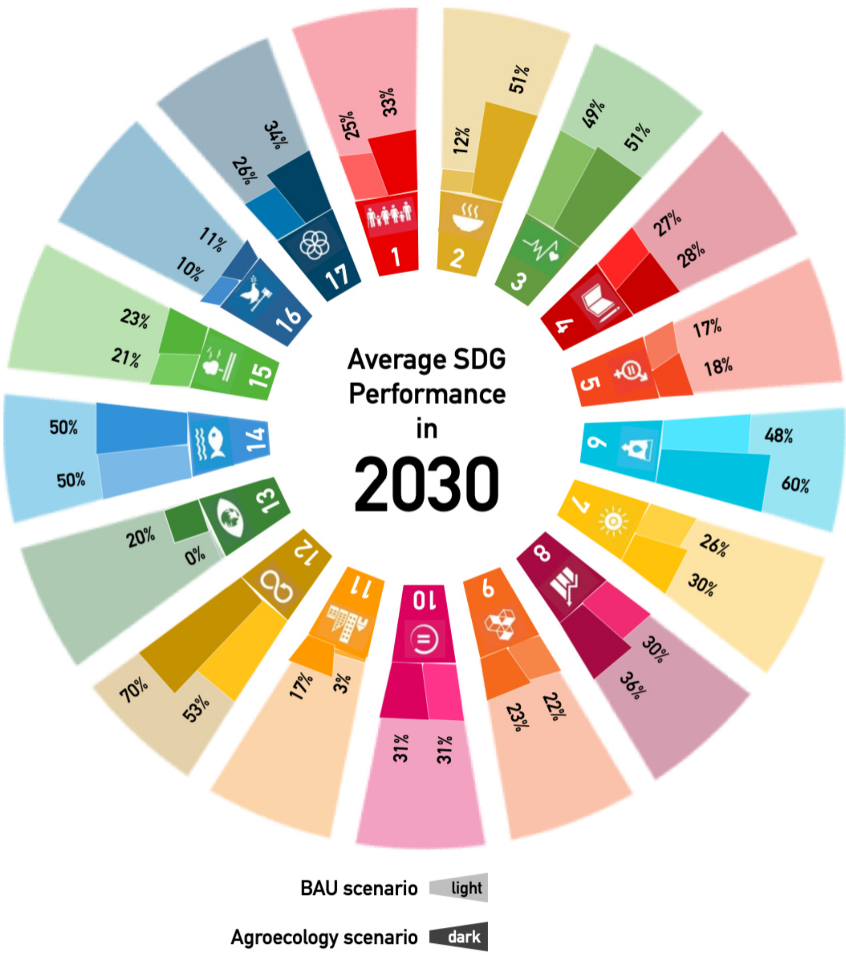
The Impact of Agroecology on the Achievement of the Sustainable Development Goals (SDGs) – An Integrated Scenario Analysis –

by the Millennium Institute

December 2018



Commissioned by Biovision Foundation

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Abstract

This study examines the impacts of a set of agroecological interventions for a typical semi-arid African country on the achievement of all the Sustainable Development Goals (SDGs). The policy analysis utilises the Threshold21-iSDG model, developed by the Millennium Institute (MI), which integrates the social, economic and environmental dimensions of sustainable development into one framework. The assessment presents and compares results for the 17 SDGs under two different scenarios: Business as Usual (BAU) and Agroecology (AE). The interventions implemented in the AE scenario are inspired by Andhra Pradesh's Zero Budget Natural Farming (ZBNF) approach and cover the 10 agroecological principles of the Food and Agriculture Organisation of the United Nations (FAO). The results show that implementation of the AE scenario significantly improves the performance of 12 SDGs and doubles the achievement levels of four of them. Further, the analysis reveals the causal relations and interactions that generate impacts. Finally, simulating the model allows identification of the individual contributions of each intervention as well as synergies emerging from interactions. Based on these findings, this study suggests several recommendations with regard to the implementation of agroecology to enhance achievement of the SDGs.

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For more information on agroecology, visit: www.agroecology-pool.org.

1. Introduction

In September 2015, the United Nations (UN) Assembly adopted the 2030 Development Agenda and its 17 SDGs, a comprehensive framework designed to guide development efforts over the following 15 years. Agriculture, with its connections to key aspects such as food security, income (especially of the rural poor), ecosystems, climate change, gender and health, is a crucial sector for achievement of the goals. However, it has been highlighted that a transformation towards sustainable agriculture is necessary to improve SDG achievement (FAO 2018b, Caron et al. 2018).

In this context, the goal of this modelling analysis is to assess the impact of a set of agroecological interventions on the achievement of all SDGs for a typical semi-arid African country. The interventions are based on the 10 principles of agroecology (FAO 2018a) and inspired by Andhra Pradesh's ZBNF approach (FAO 2016). With the selection of ZBNF-related interventions, we ensure that the interventions have been successfully tested and applied in a real context on a large scale – in this case by hundreds of thousands of farmers in India where yields, food autonomy, income and health, among others, were successfully increased (Khadse et al. 2018, see Infobox 1).

INFOBOX 1 - **Zero Budget Natural Farming (ZBNF)**

The ZBNF approach aims to support farmers to become independent from external inputs. It promotes nutritional self-sufficiency in that all required nutrients are available in healthy soil and do not need to be added to the system from outside. The approach helps small-scale farmers increase their net income by using natural farming approaches while increasing the inherent resiliency of their farming system. For example, in India where ZBNF originated, it is estimated that millions of farmers use ZBNF, and surveys report increased yields, seed diversity, product quality, household food autonomy, income and health, alongside reduced farm expenses and credit needs (Khadse et al. 2018). The government of Andhra Pradesh (one of the 29 Indian states) has launched a scale-out plan to transition six million farmers from conventional synthetic chemical agriculture to ZBNF by 2024 (UNEP 2018).

Policy planning and impact assessments with the goal of SDG achievement are difficult because of the multi-disciplinary, interconnected and complex nature of the 2030 Development Agenda. The fact that policies in one sector have an effect on several other sectors and goals, but not necessarily in a linear way, highlights the need for integrated planning across sectors to develop coherent policies (O'Connor et al. 2016). In order to address such challenges, MI has developed the Threshold21-iSDG model. By integrating the social, economic and environmental dimensions of sustainable development into one framework, the iSDG model enables broad, cross-sector, long-term analysis of alternative policies for achieving the SDGs (for more information, see www.millennium-institute.org/isdg and Infobox 2).

INFOBOX 2 - **Threshold21-iSDG model**

The iSDG model (MI 2016) was constructed starting from the well-vetted, time-tested and validated Threshold21 (T21) model, which has evolved over the past 30 years through research and application by MI (Barney 2002). The iSDG model is a System Dynamics-based model for comprehensive and participatory development planning. It integrates economic, social and environmental factors, and represents the important elements of complexity like feedback relationships, non-linearity and time delays that are fundamental to effectively addressing development issues. The model can be customized to country-specific conditions and simulates the medium- and long-term consequences of alternative policies. A recent survey of existing modelling tools for integrated assessment (UN 2015) indicates the inability of the best known global modelling frameworks to provide a comprehensive perspective on the SDGs. Although at the national level some comprehensive static analytical frameworks are being developed (Sachs et al. 2016), to our knowledge the iSDG model is the only scenario tool for national planning addressing the 17 SDGs (OECD 2016). The model evaluates SDG impacts based on a subset of the SDG indicators proposed by the UN (UN 2016), and it measures the performance of 79 SDG indicators covering all 17 SDGs and selected based on data availability (ICSU and ISSC 2015). For each indicator we introduce a target value[1] for 2030 and calculate performance as the percentage attainment of these targets.

[1] The target value is the value that a specific SDG indicator should reach to achieve a 100 per cent level of attainment. The target values are based on UN definitions where these are explicitly indicated, and on discussions with an expert team from Governments.

In this study, we present and compare the results for the 17 SDGs under two different scenarios: the BAU (continuation of current policies) and the AE (implementation of agroecological interventions). Simulating the model allows assessment of the level of SDG achievement in the two scenarios, identification of the individual contributions of each policy and the synergies emerging from policy interactions. To assess long-term impact, the level of achievement in 2050 is also shown. The explorative scenarios are not to be taken as precise forecasts – which are not feasible over the time horizon we consider – nor are they meant to be final. They have been designed and analysed with the purpose of informing a comprehensive policy process by facilitating the identification of challenges and coherent strategies for achieving the SDGs.

2. Policy Scenario Analysis

2.1 Description of Scenarios

To assess the impact of agroecological interventions on achievement of the 17 SDGs, we analyse two scenarios. In the BAU scenario we assume that current policies are continued into the future; in the AE scenario we assume implementation of the agroecological principles proposed by FAO (2018a), especially those related to the ZBNF approach (FAO 2016). The ZBNF approach was chosen to ensure feasible implementation. With hundreds of thousands of farmers applying this approach and improving their situations, it has been shown that the proposed interventions can be successfully implemented (see Infobox 1).

Table 1 presents the selected interventions and how these have been translated into policies and assumptions in the model. They are assigned to FAO's ten principles of agroecology. However, since agroecology constitutes a holistic approach in which principles and interventions are interlinked, the table also indicates that several interventions can be assigned to various principles. Further, the principles and interventions touch upon aspects in each of the three sustainable development dimensions: society, economy and environment. The two columns on the right show the level of implementation in the two scenarios in absolute values. In this study, real data from a specific, typical semi-arid African country is used and the model is customized accordingly. The BAU column presents the current state of practice (that would be continued into the future) and the AE column shows the absolute value (not the changes compared to BAU) that is implemented in 2020 (unless otherwise indicated).

The levels of implementation and the necessary changes between the two scenarios would depend on the particular country and its current policies. For example, although the support of farmers' organizations is a key pillar of ZBNF, in this study the AE scenario only assumes a small increase of this support to achieve the goal of a high degree of organized farmers because that support is already high in the BAU scenario. Further, in this study the AE scenario is characterized by a change of farming techniques (e.g. implementation of agro-livestock systems by around 40 per cent of farmers) and the inherent social and economic consequences (e.g. food autonomy or job creation) that is supported by a shift of government expenditure. This is mainly from irrigation (reduction of expenditure but investing in higher efficiency) towards key aspects of agroecology (e.g. sustainable land management, etc.), thus reducing total government expenditure (the policies in this list total up to 2.47 per cent of Gross Domestic Product [GDP] in the BAU and 1.69 per cent in the AE).

Table 1 - Policies and assumptions for FAO's ten principles of agroecology and their evolution in the AE compared to the BAU scenario

FAO principles of agroecology	Intervention	Policy assumption in iSDG	BAU	AE[2]
Efficiency	Increase resource use efficiency (e.g. replace inefficient with efficient irrigation equipment)	Expenditure for agriculture water efficiency and irrigation equipment (% of GDP)	1.85%	0.15%
	Reduce mineral fertilizer and increase natural fertilizer use (e.g. mulching, use of crop residues, cow dung and urine) [see Synergies]	Natural fertilizer use per ha of harvested area (ton/ha/year)	0.03	4
Recycling		Expenditure for fertilizer subsidies (% of GDP)	0.052%	0.005%
	Reduce pesticide use and increase integrated pest management (e.g. use of cow dung, botanical extracts) [see Resilience]	Average biological pest control use per ha of harvested area	0	0.1
Synergies		Pesticide use per ha of harvested area (kg/ha/year)	0.12	0.06
	Implement agro-livestock integration (e.g. use of local breeds, such as desi cow) [see Recycling]	Arable land used for agro-livestock	0%	33%
Diversity		Pasture land used for agro-livestock	0%	7%
Resilience	Diversify production and increase income	Base salary for farmers[3]	75%	80%
	Invest in climate change adaptation (e.g. local seed use, contour farming, moisture management, research, restore habitats, etc.)[4]	Expenditure for climate change adaptation in agriculture (% of GDP)	0%	2050: 0.12%
	Enhance provisioning of ecosystem services (e.g. pollination/soil health by intercropping, etc.) [see Synergy]	Expenditure for sustainable land management (% of GDP)	0.013%	0.613%
Co-creation and sharing of knowledge	Dissemination of technology without state involvement (e.g. Master Farmer concept, farmer to farmer propagation, etc.)	Average knowledge dissemination about sustainable agriculture by organized farmers (person/farmer/year)	0	0.4

[2] The column shows the absolute level that is adopted in 2020 and persists until 2050, if not indicated otherwise.
[3] The % indicates the minimum salary relative to average salary.
[4] We use investments in adaptation for agriculture in a rather broad sense that includes covering of adaptation costs for agriculture, water supply and natural ecosystems (UNFCCC 2007), respectively agriculture, extreme weather events and water supply/flood protection (UNEP 2014a). Based on the mentioned adaptation cost literature, these adaptation investment needs total up to around 33-42 per cent of total adaptation investment needs.

Circular and solidarity economy	Reconnect producers and consumers by strengthening short food circuits and local markets, including small-scale production and processing [see Culture and food traditions]	Waste share reduction due to small-scale mills	0%	20%
		Processing share increase due to small-scale mills	0%	20%
Responsible governance	Support farmers' organizations[5] improving access to information[6], training, markets, inputs and capital	Expenditure for farmers' organizations (% of GDP)	0.556%	0.656%
	Prevent the depletion of natural resources through land and natural resource governance	Expenditure for additional reforestation (% of GDP)	0%	0.15%
Culture and food traditions / **Human and social value**	Increase the potential of territories to sustain their peoples by reconnect-ting food habits and culture, and food production and consumption	Proportion of population below food poverty line with access to non-marketed food	55%	57%
	Job creation by knowledge and labour-intensive agroecological production [see Culture and food traditions]	Proportion of adult population with partial employment	40%	45%
	Empower people, especially women at household, community levels and beyond by building knowledge through collective action and creating opportunities for commercialization (e.g. by promoting their participation in producer groups)	Women's economic opportunity index	0.387	2030: 0.595
		Gender gap in employment in relation to gap in education[7]	0.22	2030: 0.15
		Education gender bias (secondary, tertiary)	70%, 60%	2050: 85%, 70%
		Voice and accountability (scale -2.5 to 2.5)	0.253	2030: 0.742
Total government expenditure for the interventions (% of GDP)			2.47%	1.69%

[5] The institutions include Federation of Farmer Self Help Groups, Village and Cluster Federations, Farmer Producer Organizations, etc. They facilitate trainings, can implement projects such as ZBNF input village shops and increase key benefits like solidarity, savings and credit, vulnerability reduction, insurance, aggregation of production, local marketing, quality assurance and traceability, etc.

[6] The support of Information and Communications Technology (ICT) in these organizations plays an important role as it facilitates linking with markets, e-tracking adoption, monitoring of crop conditions, e-marketing, access to climate change and geo-mapping data, etc.

[7] A value less than one means that the disparities in employment rates are lower than in completions of education. A value greater than one would mean greater disparities.

2.2 Simulation Results of Scenarios

2.2.1 Achievement levels for the 17 SDGs in 2030 and 2050

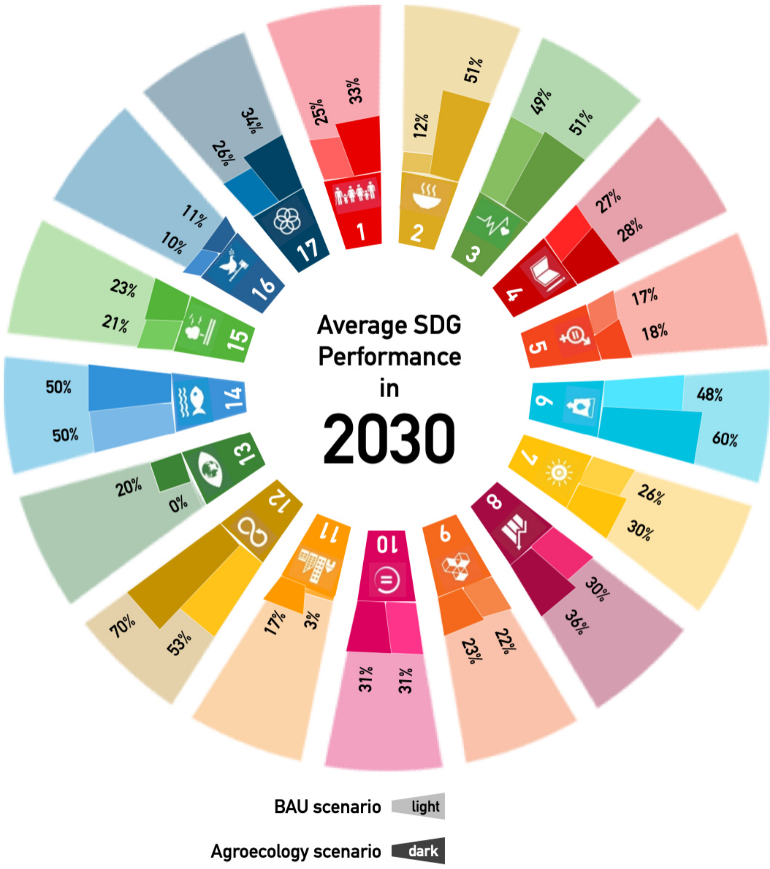

Figure 1 - Achievement of the 17 SDGs in the BAU and AE scenarios in 2030

Figure 1 illustrates the level of achievement of the 17 SDGs in 2030 in the two scenarios. The figure indicates that the performance over all 17 SDGs in the BAU scenario is only 26 per cent. Assuming the implementation of the AE scenario, performance can be improved to around 34 per cent in 2030. In the BAU scenario in 2030 only two SDGs arrive at over 50 per cent achievement (SDG 12, 14), while the AE scenario includes three additional goals (SDG 2, 3 and 6).

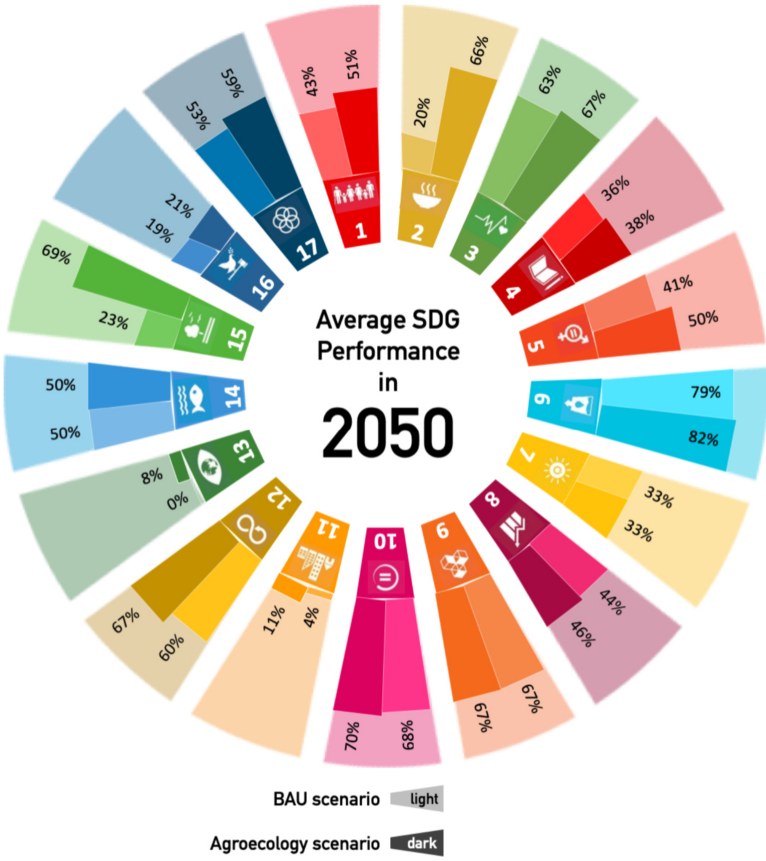

Figure 2 - Achievement of the 17 SDGs in the BAU and AE scenarios in 2050

In 2050 (see Figure 2), the overall performance of the AE scenario rises to 50 per cent, while performance is only 41 per cent in the BAU scenario. In 2050, the performance of seven goals (SDG 3, 6, 9, 10, 12, 14, 17) is over 50 per cent in the BAU scenario; the AE scenario includes four additional goals (SDG 1, 2, 5, 15).

This overall improvement is mainly due to the very substantial improvement (more than two-fold performance increase) compared to the BAU scenario of four goals (SDG 2, 11, 13 and 15) and the relevant improvement of performance between 10 and 35 percent in the AE compared to the BAU scenario for eight goals. For five of those goals (SDG 1, 5, 12, 16, 17), the advantage persists until 2050, while it is only temporarily relevant for the other three goals (SDG 6, 7, 8), meaning that the advantage that exists in 2030 decreases by 2050. This is due to the fact that at some point between 2030 and 2050 the targets of some indicators are already reached in the AE scenario so that a further improvement in the BAU scenario decreases the difference to the ceiling of 100 per cent, indicating not necessarily a reduction in performance but rather an overachievement in the AE scenario. Finally, four goals (SDG 3, 4, 9, 10 and 14) did not have significant improvement of performance levels. The following paragraphs analyse the results by goal according to this categorization.

2.2.2 Substantially improved performance in AE scenario

SDG 2 (Zero Hunger) exhibits an increase from 12 per cent in the BAU scenario to 51 per cent in the AE in 2030, reaching 66 per cent in 2050. The achievement level in the BAU scenario persists at a low level with 20 per cent in 2050. Hence, the analysis reveals that the proposed policies are capable of more than tripling the achievement level of SDG 2 in 2030.

The strong increase in public expenditure for training in sustainable land management in combination with higher expenditure for farmers' organizations, knowledge dissemination from farmer to farmer, increased use of natural fertilizers and biological pest control leads to higher productivity and more sustainable food production. Agriculture production is further increased by agro-livestock integration and investment in agriculture adaptation, reducing the negative impact of climate change on agricultural productivity – especially in the long term.

The joint implementation of all these policies leads, for example, to a doubling of crop production in the AE scenario compared to the BAU in 2050, also increasing the salaries and wages earned in the sector. This is supported by the diversification of products. In addition, the augmented labour intensity in the AE scenario leads to an increase in agriculture employment. Both the increase of earnings in the agriculture sector and the changed distribution of those earnings result in a decrease of poverty. This, together with reduced waste and a larger portion of the population with access to non-marketed food due to the reconnection of food production and consumption in the AE scenario, is the main reason for the improvement in food security. The results also indicate that implementation of the proposed policies can significantly contribute to the achievement of SDG 2, for example reducing undernourishment by 28 per cent in 2050 compared to the BAU scenario, but that additional policies – for example addressing unemployment and poverty in other sectors – are necessary to eliminate hunger.

One reason for the improvements with SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) in the AE scenario compared to the BAU is the increase of expenditure for agriculture adaptation to climate change resulting in a reduction in economic damage and the population affected by natural disasters. Since we apply a rather broad definition of agriculture adaptation measures, the investments counteract a significant part of the impact. However, with the increasing frequency of natural disasters, the absolute damage increases even with the implementation of adaptation measures, explaining the decreasing trend in achievement levels for SDG 11 and 13 and indicating the necessity of investment in adaptation for all sectors.

For SDG 11 an additional factor improves AE scenario performance. The increase in agriculture production (see section on SDG 2) initiates a diffusion of positive effects throughout the whole system, including the activation of important reinforcing feedback loops that result in higher GDP. For example, the increase of household revenue due to augmented agriculture production also allows for an investment increase in other sectors, leading to higher production and contributing to a higher GDP, and allowing for more investment in the three sectors thereby reinforcing GDP growth. In addition, increased GDP also leads to higher government revenue and thereby enabling more government investment, for example in education, health, infrastructure and increasing productivity – and consequently higher GDP. These mechanisms are visible in the achievement of SDG 11 because the increase in government revenue allows higher expenditure for waste management, increasing the share of waste collected and hence the achievement level of SDG 11. These results illustrate the interlinked nature of the system and reveal that changes in agriculture extend outwards and can be the beginning of positively reinforcing developments.

As to SDG 15 (Life on Land), the improved performance in the AE scenario is mainly due to the strong increase in government expenditure for reforestation, affecting forests and consequently biodiversity levels. While the decreasing trend of forestland in the last decades further continues in the BAU scenario, the prompt reforestation in the AE scenario quite quickly slows down such a trend and even starts to increase forest cover after a period. However, until the end of the simulation in 2050, even notable efforts are not able to restore the level of forest cover to that of 1990. Further, the simulation reveals an important delay: it takes more than ten years to initiate a reversal of the decreasing trend in forest cover, which is observed only after 2030. This is also the reason why the difference in achievement levels is rather small in 2030 while it is very significant in 2050. Like forestland, degraded land has a similar behaviour only in the reverse: While the increase of degraded land over the last twenty years continues in the BAU scenario, the degradation stops around 2030 in the AE scenario and degraded land even decreases over the following two decades from 2030 to 2050. This is due to reforestation (rehabilitating degraded land) and the high increase in sustainable land management (reducing land abandonment). However, we find a similar delay with forests so that, again, the level of 2015 is only reached around 2050. The results emphasize the importance of the agroecological principle “responsible (natural resource) governance” to prevent the depletion of natural resources, but also the necessity of quick action as there are significant delays between policy and effect.

2.2.3 Persisting relevant improved performance in AE scenario

The increase in performance of SDG 1 (No Poverty) has several roots, including the increase in revenue (especially of the rural poor) generated by the production increase but also by the diversification of agriculture products and the increase in employment (reducing unemployment and improving distribution among the population), as described in the section on SDG 2. The simulated behaviour also emphasises one important element: The increase of difference with this goal’s poverty and health indicators is caused by the positive feedback loops that lead to the reinforcement of improvement over time (see section on SDG 11). This increasing difference is counteracted by the decreasing difference of performance for the indicators concerning economic damage and population affected by natural disasters (see section on SDG 11), explaining that the absolute difference between the two scenarios remains over the years.

The improved performance of SDG 5 (Gender Equality) is largely due to the reduction of the education bias in secondary and tertiary schools. The simulations indicate that the effect of policies that target improvement for already adult women (women's economic opportunity index, gender gap in employment) is limited, as long as it is not combined with the increase of female enrolment. These changes are very important as they target the roots of inequality, empowering future generations of women in their self-determination and improving several indicators for SDG 5 such as proportion of female legislators, senior officials and managers, as well as contraceptive prevalence. However, there is a strong delay between ameliorations in gender equity in education and the visible impact, for example on gender equity in employment, explaining why the improvement in performance is rather small in 2030 but growing at an increasing rate and reaching an achievement level of 50 per cent in 2050. Therefore, as is done in the AE scenario, it is key to empower women, especially in rural areas, assuming that in households with empowered women girls are sent to school more often and thereby decreasing the gender gap in education and consequently improving gender equality in future generations. Nevertheless, the results also reveal that additional changes are necessary to increase SDG 5 achievement levels such as further increasing female enrolment and consequently equality in education, higher investment in contraceptive prevalence and further strengthening gender equality in employment.

The significant improvement of SDG 12 (Responsible Consumption and Production) performance from 53 per cent in the BAU scenario to 70 per cent in the AE in 2030 is mainly due to the reduction of pesticide dispersion in the environment. However, the difference between the two scenarios is higher in 2030 than in 2050 (60 per cent achievement in the BAU and 67 per cent in the AE) for two reasons. First, the amount of harvested area increases with time in the AE scenario (for example due to the implementation of agro-livestock systems), which lead to a reduction of the difference in the total amount of pesticide use between the two scenarios. And this in spite of a lower amount of pesticide use per hectare in the AE scenario. Second, the simulation results reveal the ambivalent effects of economic development on indicators concerning material footprints. After an improvement in performance to 2030 because of more efficient resource use, we observe a decrease and slightly worse behaviour in the AE than in the BAU scenario because increase in GDP leads to larger absolute material footprints and greater material consumption in other sectors, exceeding the effect of improved efficiency such as a better footprint per output. Thus, the improvement of GDP and income generated by agroecological interventions necessitates additional interventions in other (production) sectors to ensure sustainable consumption and production patterns, for example further promoting material consumption efficiency and recycling.

The main factor for the continuously increasing improvement in performance of SDG 16 (Peace, Justice and Strong Institutions) is the decrease of violence-related death rates in the AE scenario compared to the BAU. This is caused by improvements in income, food security, education levels and even governments' per capita health expenditure generated by the changes in the AE scenario. These improvements then disseminate to very different aspects of the system and activate reinforcing mechanisms for development (see SDG 11 section).

The improvement in performance of SDG 17 (Partnerships for the Goals) reflects the substantial decrease of public debt interest as a share of exports in the AE scenario. Although exports are higher in the AE scenario, the decrease in interest payments by far exceeds the export increase due to a number of causal relations. Because of the increase in GDP, government revenue increases (although the tax share remains), allowing both an increase of all government expenditure (for example for health, education, agriculture, etc.) as well as a reduction of the yearly government deficit. This leads to lower debt levels in the AE scenario compared to the BAU, and consequently to lower interest payments and further reducing the yearly deficit. The result is that around 2033 the government no longer has a deficit but rather a surplus, allowing the start of debt repayments both foreign and domestic. As a consequence, the stock of total debt – that has been increasing since 1990 – starts to decrease in the mid-2030s in the AE scenario while it continues to increase in the BAU. Also, the interest payments decrease in the AE scenario, facilitating even higher repayments.

Therefore in 2050 in the BAU scenario the total debt-to-GDP ratio is more than 20 per cent, and decreases to less than three per cent in the AE scenario. The only reason for the decrease of difference in performance between the scenarios for the last 10 years is that the goal for this indicator (interest on public debt as share of exports) of three per cent is already reached around 2040 in the AE scenario. This is also due to the fact that the scenario simply assumes a continuation of government expenditure as a share of GDP and the use of additional resources for debt reduction. Of course, the government could decide to increase investment instead, especially once the debt level goal is achieved, increasing the positive impacts in the select sectors. Thus, the simulation results reveal that the AE scenario is capable of reducing government expenditure in a way that significantly reduces debt levels, allowing an increase of government expenditure into the future.

2.2.4 Temporary relevant improved performance in AE scenario

The main distinction in the performance of SDG 6 (Clean Water and Sanitation) is that investment in agriculture water efficiency generates a decrease in total water withdrawal per unit of GDP. However, towards the end of the simulation, both scenarios reach the target of 75 per cent of the 2015 level. This eliminates the difference in performance for the achievement calculation, although the better performance for that indicator (lower water withdrawal per unit of GDP) in the AE compared to the BAU scenario remains. The small difference in achievement levels is due to increased access to improved sanitation because of higher government expenditure (see SDG 11 section). Hence, the significant decrease in expenditure for irrigation, and instead investment in water efficiency, as in the AE scenario, not only allows the government to save money but also generates better performance in key aspects such as water use, although this is only partly visible in the calculated SDG performance.

The increase in performance of SDG 7 (Affordable and Clean Energy) in 2030 is caused by an increase of the percentage of the population with access to electricity, mainly due to higher income levels in the AE scenario. However, the difference disappears in the mid-2030s when the target of 100 per cent access is reached in both scenarios.

Concerning SDG 8 (Decent Work and Economic Growth), analysis of the indicators reveals an important difference between the two scenarios due to the increase of production and employment that starts in the agriculture sector but in the long run spreads to all sectors (see SDG 11 section). The difference decreases over time because some indicators achieve the target in both scenarios, for example halving the "share of youth not in education employment or training". However, although the difference in SDG performance fades away when both scenarios reach the target around 2040, the difference for the indicator "youth not in education, employment or training" remains and even increases. Similarly, the results indicate an important difference in achievement levels concerning the per capita growth rate of GDP in 2030 due to the very ambitious target of seven per cent and the fact that the per capita growth rate falls below current levels in both scenarios around 2040. The achievement level is zero in both scenarios in 2050, although the difference in per capita growth rate of GDP remains. Only the difference in performance between the two scenarios regarding the unemployment rate persists until 2050 and increases over time due to activated positive feedback loops. Thus, the AE scenario produces significant improvements concerning decent work and economic growth, but their visibility decreases over time when the targets for 2030 are reached in both scenarios.

2.2.5 No relevant improved performance in AE scenario

For SDG 10 (Reduced Inequalities), there is an improvement in indicators such as a reduction of "proportion of people living below 50 per cent of median income" and the Gini coefficient. However, the visibility of improvement in SDG achievement is reduced because of the achievement of some SDG targets and the choice of "labour share" as an indicator to measure this goal (to be discussed when analysing the contribution by policy).

Although there are small improvements in SDG 3 (Good Health and Well-Being), SDG 4 (Quality Education) and SDG 9 (Industry, Innovation and Infrastructure), a significant amelioration of these SDGs requires policy action in their respective sectors.

SDG 14 (Life below Water) could be significantly improved when the problem of overfishing is addressed (for example by introducing fishing quotas). Such an intervention could be proposed as a policy in a broader AE scenario to ensure equitable access to land and natural resources and implementation of the principle of responsible governance, but is not part of the AE scenario presented in this study.

2.2.6 Policy contributions and synergies

Figure 3 illustrates the effect of each policy simulated in the scenarios on the achievement of the 17 SDGs, highlighting their contribution to total performance. For example, for SDG 2 (Zero Hunger), the graph shows that achievement is around 12 per cent in the BAU scenario and that several interventions indicated by different colours contribute to the increase, such as sustainable land management (brown) (as a single policy causing an additional achievement of around 14 per cent) and farmers training farmers (dark pink) (generating an increase of around 17 per cent). Smaller contributions of around one to two per cent can be attributed to agro-livestock integration (green), changes in fertilizer use (dark green), investment in climate change adaptation in agriculture (orange), and increased access to non-marketed food (turquoise). Furthermore, achievements caused by synergies (blue) are indicated, in the case of SDG 2 around three per cent, and the total performance (black dot) for SDG 2 is shown at around 51 per cent.

Synergies

Synergies mean that the results of joint implementation of all policies are higher than the sum of single policy achievements. Such synergies can be caused by various mechanisms through which a policy leads to better enabling conditions for another policy. For example, for SDG 2, large synergies emerge from the interaction of productivity improvement (sustainable land management, natural fertilizer use, Integrated Pest Management [IPM] and knowledge dissemination by farmers), enlargement of cultivated area (through agro-livestock integration), the decrease of negative effects from climate change (adaptation) and an increase in the number of poor with access to non-marketed food. The fact that there are no negative synergies demonstrates that the AE scenario is comprehensive and incorporates policies that support rather than counteract one another.

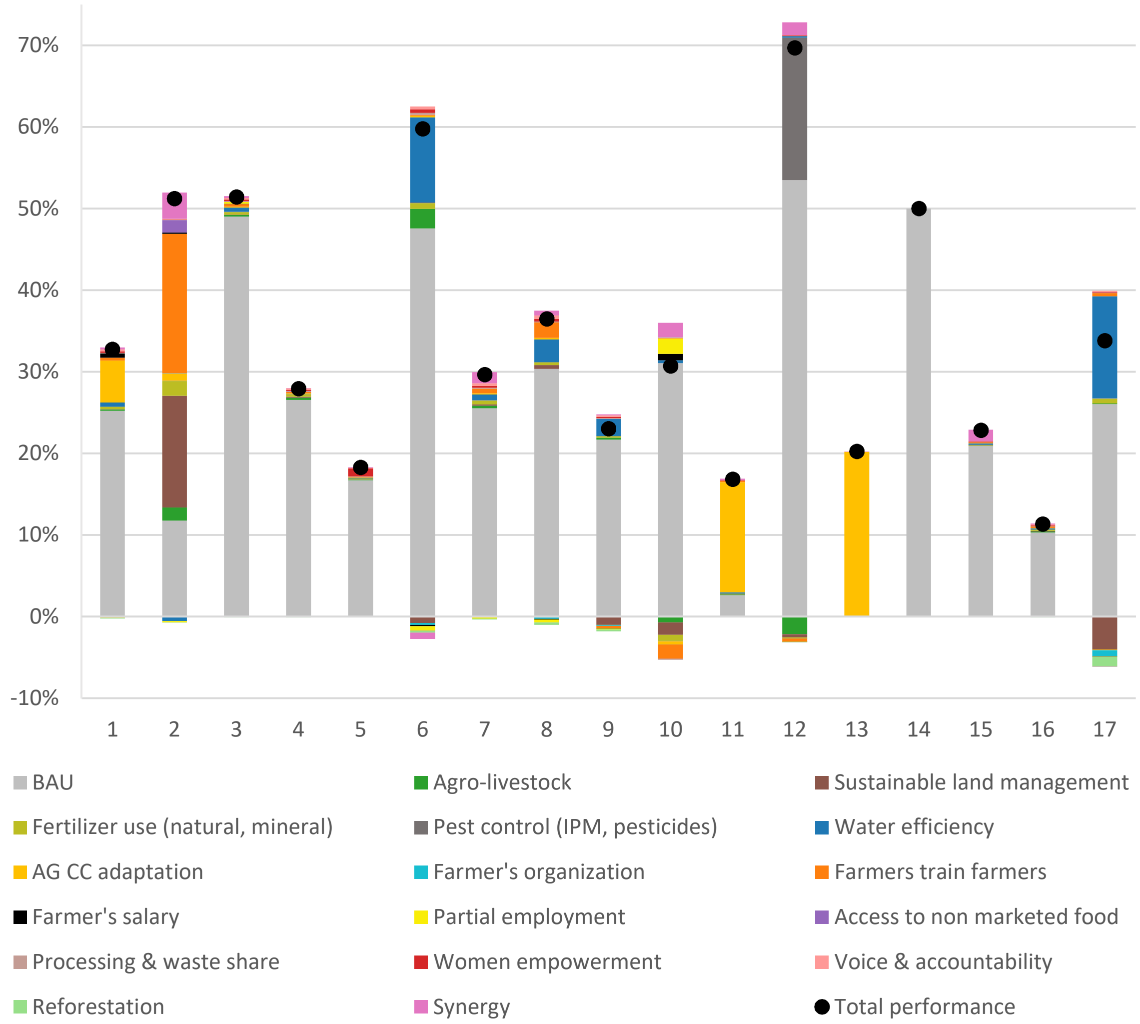

Figure 3 - Contribution of each policy in the AE scenario to the performance of the 17 SDGs

Policy impact on one or several goals

Apart from synergies, Figure 4 shows that some interventions that mainly affect one SDG have limited impacts on others. For example, the intervention concerning pest control (meaning the increase of IPM practices combined with the reduction of chemical pesticide use) generates an additional improvement in the performance of SDG 12 (Responsible Consumption and Production) of around 18 per cent.

Most of the interventions affect several goals. One example is the simulated intensified knowledge dissemination from farmer to farmer, which does not only affect SDG 2 (Zero Hunger) but also leads to reductions in poverty, undernourishment and mortality, as well as to higher GDP growth, which then fosters greater social services expenditure. Similarly, the voice and accountability increase leads to productivity increases and in the provision of social services, with positive impacts on nearly all goals.

The results indicate the importance of climate change adaptation in agriculture, which decreases the negative effects of climate change on productivity as well as, due to natural disasters, the economic damage and impact on the population. Beyond the impact on SDG 5 indicators, which is still rather small in 2030 but increases over time, the empowerment of women leads to improvements in education, productivity, income and nutrition. The interventions on water efficiency, combining the increase of investment in greater efficiency with strong reduction of expenditure for irrigation, cause, through the reduction of water use, a significant improvement in SDG 6 (Clean Water and Sanitation). Secondly, the interventions allow the government to save money, reducing debt levels and interest payments, freeing money for private investment and consequently increasing production, government revenue and expenditure for social services. The importance of these policies for several SDGs emphasizes the interconnectedness of the system and the importance of integrated analysis.

Negative effects

Finally, Figure 4 shows that when simulated some interventions alone cause negative effects, but the analysis reveals that those effects are negligible. For example, the figure indicates a decrease of achievement of SDG 10 (Reduced Inequalities) exactly by those interventions that increase agriculture production and the performance of SDG 2 (Zero Hunger), such as training in sustainable land management or farmers training farmers. This is due to the fact that "average labour share" is taken as an indicator for the achievement calculation (UN 2016). However, the results indicate a problem with this decision, since the labour share remains low or even decreases if agriculture production increases,[8] although the increase of agriculture production in principle does not involve an increase of inequality. On the contrary, due to the fact that the poor in the population work in agriculture, the increase in agriculture production leads to a reduction of inequality. This is visible looking at a more comprehensive indicator such as the Gini coefficient that decreases on an increasing rate in the AE scenario compared

[8] This has several reasons. First, labour share in agriculture is generally quite low (around 10 per cent compared to around 60 per cent in industries and services), one reason being that land is seen as part of capital. Secondly, the increase of agriculture production increases the weight of the low labour share, decreasing the average labour share.

to the BAU. Similarly, the results show that policies that involve an increase of government expenditure (for example trainings in sustainable land management or reforestation) affect the performance of SDG 17 (Partnerships for the Goals) in a negative way, because they lead to an expenditure increase and consequently of debt levels as well. However, once the increase in expenditure is compensated for by a decrease in another area (as is done in the AE scenario by the reduction of irrigation expenditure), the negative contribution is prevented. Hence, the result for SDG 17 mainly demonstrates the expenditure shift from irrigation to other intervention areas. In this context, it is interesting to note that Figure 4 reveals a fundamental problem with policies involving a large delay between the required effort and the reward, for example reforestation. In 2030, the increase of expenditure for reforestation causes a negative effect on SDG 17 but not yet a positive impact on SDG 15 (Life on Land), although the results show that the positive impact in 2050 is remarkable (tripling the achievement of SDG 15 compared to the BAU scenario). This indicates the importance of long-term simulation, analysis and planning, for elements of sustainability in particular are often only visible in the long term.

3. Key Findings

The iSDG simulation analysis led to eight primary findings regarding the assessment of the impact of a set of agroecological interventions for a typical semi-arid African country on the achievement of all SDGs by comparing the AE scenario (that assumes the implementation of agroecological principles) with the BAU (that assumes that current policies are continued into the future).

1 The AE scenario generates significant improvements in SDG achievement compared to the BAU scenario

- **Overall performance across the 17 SDGs is improved by the AE scenario** - In 2030, the AE is 35 per cent while the BAU scenario is 26 per cent; in 2050, AE is 50 per cent compared to 41 per cent in the BAU.
- **The AE scenario lifts additional SDGs above 50 per cent** - In 2030, the achievement of only two SDGs (SDG 12, 14) is over 50 per cent in the BAU, while in the AE scenario this is the case for three more (SDG 2, 3 and 6). In 2050, the performance of seven SDGs (SDG 3, 6, 9, 10, 12, 14 and 17) is over 50 per cent in the BAU and the AE scenario has four more (SDG 1, 2, 5, 15).
- **Four goals have their performance more than double in the AE scenario compared to the BAU** - These are SDG 2 (Zero Hunger), SDG 11 (Sustainable Cities), SDG 13 (Climate Change) and SDG 15 (Life on Earth). Further, the two-fold increase for SDGs 2, 11 and 13 is reached in 2030 and persist in the longer term. For SDG 15, it takes until 2050 to double the performance.
- **Eight goals show performance increases between 10 and 35 per cent in the AE scenario compared to the BAU** - While the amelioration persists in this range for four goals over the simulation period (SDG 1 [No Poverty], SDG 12 [Responsible Consumption and Production], SDG 16 [Peace, Justice and Strong Institutions] and SDG 17 [Partnership for the Goals]), and the difference for SDG 5 (Gender Equality) increases over time (reaching such a level only shortly after 2030), the difference decreases after 2030 for another three goals (SDG 6 [Clean Water and Sanitation], SDG 7 [Affordable and Clean Energy] and SDG 8 [Decent Work and Economic Growth]), mainly because both scenarios reach targets for some indicators.

2 **The implementation of the AE scenario and the resulting generated improvements seem to be feasible and require lower government expenditure.**

The assumed interventions have been inspired by ZBNF, an approach that has been successfully tested and applied in a real context on a large scale in India, where it increased yields, food autonomy, income and health, among others (see Infobox 1). Furthermore, the simulation results reveal that the AE scenario does not necessarily require additional government expenditure but can even facilitate its reduction. Of course such an agricultural transformation requires strong leadership and political will from leaders and society, and additional success factors are listed in the recommendations.

3 **The precise scale of improvement and the concrete changes necessary to generate improvement must be analysed based on country circumstances.**

For example, in the presented analysis the AE scenario involves a considerable reduction of government expenditure for irrigation, allowing not only investment in agroecological interventions but also reduction of government expenditure on agriculture, and consequently a government deficit. Further, in this specific country context, the AE scenario assumes that the increase of expenditure for farmers' organizations is rather small, while it is significant for trainings in sustainable land management, and that is only because support for those organizations was already quite high, and quite low for sustainable land management in the BAU. Hence, the concrete changes necessary for transformation need to be identified based on the current situation and the specific circumstances in different countries. Consequently, the scale of improvement depends on the country and the scale of change, meaning that smaller changes (for example because the application of agroecological principles is already widespread) also generate smaller improvements and vice versa.

4 **The generated improvements are caused by generic interconnections, so their existence can be expected in other countries and dynamics can be generalized.**

Figure 4 gives a simplified overview of the main causal relations that have been identified as relevant for the presented results. The interventions (based on agroecological principles and presented in the green and purple boxes) affect key variables of the system that pass change on to further variables, some of which are used to measure the SDG achievement levels. For example, an expenditure increase for sustainable land management affects the soil nutrient balance, agriculture employment and land degradation, all factors that lead to an improvement of agriculture production and the performance of SDG 2. Further, an increase in agriculture production causes an augmentation of GDP, thereby improving SDG 8, and continues to spread, increasing government revenue, household revenue and government expenditure.

Figure 4 demonstrates the interlinked nature of the system and that changes in agriculture spread to economic, societal and environmental spheres and to various indicators of nearly all the SDGs. That is why most of the interventions affect several goals. In addition, the figure shows the inherent positive feedback loops that can be activated by changes in agriculture, starting a process of positively reinforcing developments (for example production – GDP – household revenue – investment – production; or production – GDP – government expenditure – government services – productivity – production). To increase readability, Figure 4 neither contains all the variables to measure the SDGs nor all the relevant causal relations, feedback loops or variables of the model (for more information, see www.millennium-institute.org/isdg).

5	Synergies contribute to the improvements in the agroecology scenario, revealing that it is composed of concerted interventions building a comprehensive scenario in which policies support rather than counteract one another.

Synergies emerge when the joint implementation of different policies is higher than the sum of achievement of each single policy, and they have been identified, for example with SDG 2 (Zero Hunger).

6	The generated improvements are significant, but additional policies in other sectors are necessary to fully achieve SDG targets.

This is true for SDGs with rather remote connections to agriculture such as SDG 7 (Affordable and Clean Energy), but also for SDGs with very close connections. For example, even by tripling agriculture production and reducing undernourishment by 27 per cent in 2050 compared to the BAU scenario, the achievement of SDG 2 is 66 per cent in 2050, indicating the need for additional policies addressing, for example, unemployment and poverty in other sectors.

7 **The analysis reveals significant delays between policy and effect, indicating the need for quick action.**

For example, a strong increase of expenditure for reforestation starting in 2019 only leads to a very small improvement of SDG 15 (Life on Land) in 2030 while improvement is significant in 2050, indicating the time needed for changes in specific intervention areas such as forest growth and regeneration of land and soil, as well as education and training.

8 **To assess SDG impacts, there is a need for comprehensive long-term analysis that integrates the interaction between different spheres, feedback loops and time delays, and that enables the identification of synergies.**

Revealing the importance of these elements, this analysis shows that their neglect will limit the produced insights. Further, such integrated analysis demonstrating widespread and long-term impacts can be helpful for increasing acceptance for interventions that first need effort and that generate positive effects only with a long delay. Indicating where long-term effects are present may help to support the implementation of policies that truly increase sustainability.

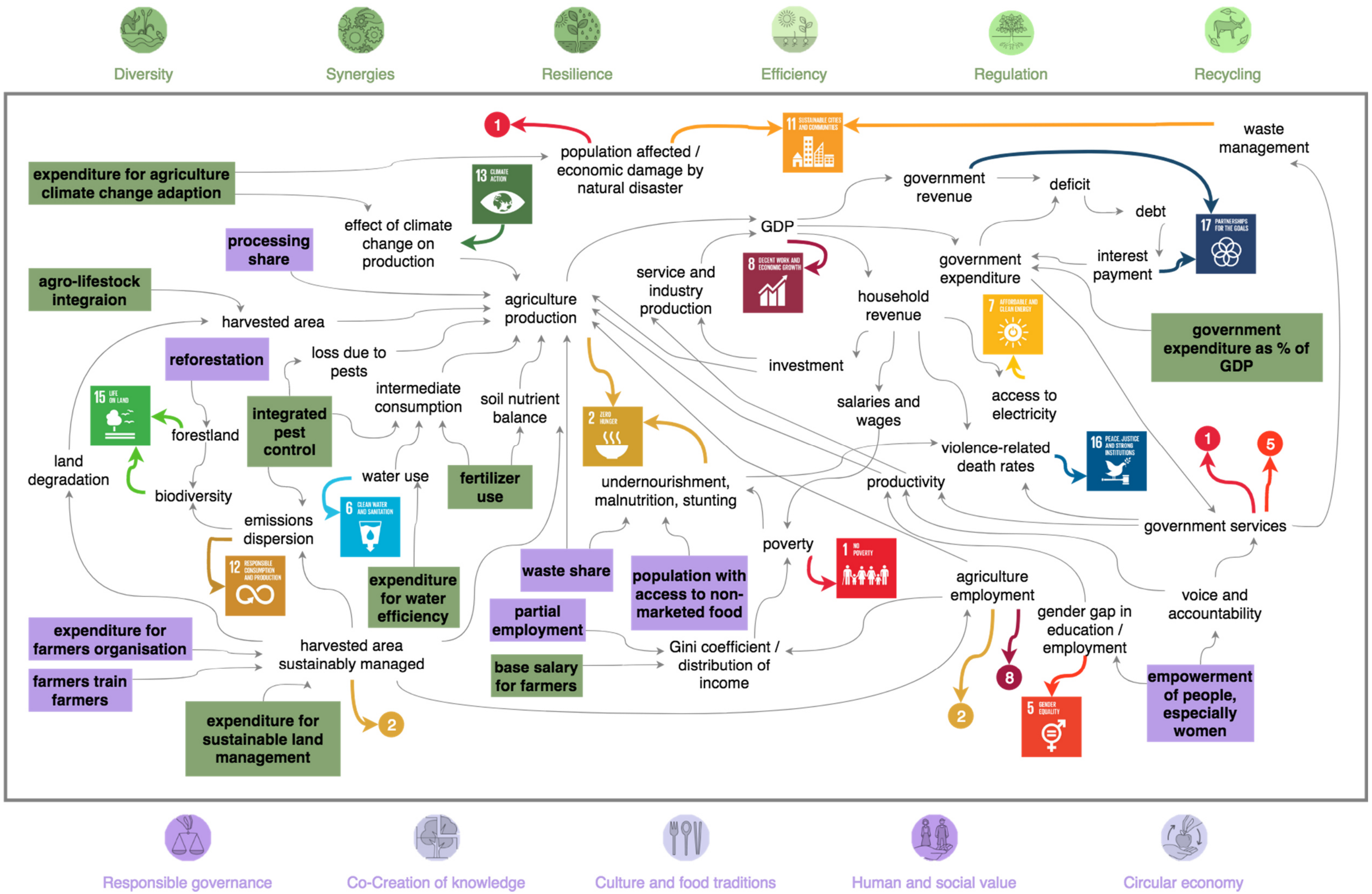

Figure 4: Causal diagram explaining the impact of the principles of agroecology and their interventions in the AE scenario on the SDGs

4. Recommendations

Based on the simulation results, we recommend to:

1. **Strengthen the implementation of agroecology as it has the potential to strongly support the achievement of the 2030 Agenda**.

2. **Consult successful approaches (such as ZBNF)** to identify and implement key interventions in order to realize the needed transformation of our agriculture and food systems. Various showcases have been documented and analysed (see for example www.fao.org/agroecology/knowledge/practices/en/ and www.agroecology-pool.org/showcases/).

3. **Take into account country-specific contexts and circumstances in order to identify concrete steps**, such as changes in government expenditure for specific policy areas based on the current level. For such an analysis, a comprehensive tool is recommended that enables integrated analysis (see for example www.millennium-institute.org/isdg).

4. **Consider key enabling factors for the successful implementation of interventions**. While this report addresses the question of *what to do* (analysing the impact of proposed interventions) rather than the question of *how to implement* interventions, other reports have identified success factors for implementation, for example of ZBNF, namely charismatic leadership, horizontal pedagogical practices, favourable public policy, local and favourable markets, effective farming practices and cultural legitimacy (Khadse et al. 2018).

5. **Address the transformation rather sooner than later.** The significant delays between policy and effect, especially for intervention areas such as education, reforestation and land or soil recovery, highlight the importance of quick action. In addition, the inherent feedback loops reinforce positive developments over time, so that improvement is greater the sooner these dynamics are activated.

6. Based on the results of this analysis, the following interventions are recommended to improve SDG achievement levels:

   i. **Increase government expenditure for trainings a) on sustainable land management, b) for farmers' organizations to strengthen the structures that support knowledge dissemination among farmers, and c) to promote farmer**

to farmer propagation. Enlarging the area that is sustainably managed, these interventions lead to the enhancement of the provision of ecosystem services, including pollination and soil health. While the positive impact of investment in training and knowledge might be realized only following a time delay, these policies are key to improving production as they are more sustainable than, for example, subsidizing inputs. They generate fewer negative effects on the environment such as dispersion, and the investment in human capital builds up a stock of knowledge that remains. This generates positive effects over decades – even when investment fades (Zuellich et al 2015).

ii. **Foster the reduction of mineral fertilizer and pesticide use while increasing the use of natural fertilizers and IPM.** Agro-livestock integration facilitates such practices, providing animal dung and strength without increasing expenditure, and allows for animal and crop production on the same land. Concrete examples successfully tested by ZBNF involve soil fertility enhancement through mulching; use of crop residues, cow dung and urine as well as organic seed treatment from local cow dung; and application of botanical extracts for pest management.

iii. **Identify and realize savings potential related to the current level of government expenditure**, for example for irrigation and subsidies for mineral fertilizers or pesticides. Focusing on efficiency (for example with water use), the reduction of external input needs (for example irrigation) and the implementation of agroecology (and especially the ZBNF approach) may reduce government expenditure, as has been the case in this analysis. That could lead to repayment of debts, lowering of interest payments and even allowing an increase of government expenditure in the future.

iv. **Significantly invest in climate change adaptation**. Such adaptation includes investment in and implementation of practices for production inherent to agroecology such as local seed use, contour farming, cover cropping, training, moisture and fire and pest management, and investment in research and infrastructure development in agriculture and connected areas such as water supply, natural ecosystems and adaptation to extreme weather events (UNFCCC 2007 and UNEP 2014a). It has been shown that this can lead to a remarkable reduction of negative climate change impacts and negative impacts on populations affected by natural disasters.

v. **Increase expenditure for reforestation** to prevent the depletion of natural resources. The analysis shows the importance of the agroecological principle "responsible [natural resource] governance" as it is possible to reverse the decreasing trend in forest cover (and if desired also concerning fish resources), but only if determined action is taken.

vi. **Empower people, especially women**. To significantly strengthen SDG 5 (Gender Equality), it is important to target the roots of inequality, specifically the gap in education, by increasing female enrolment in secondary and tertiary education and empowering future generations of women in their self-determination. Additional policies in other sectors such as education, health and employment regulations are necessary to increase SDG 5 achievement levels.

vii. **Promote the social components of agroecology** such as the reconnection of food production and consumption to increase access to non-marketed food, especially for the poor, and job creation by labour and knowledge-intensive agroecological production. These are important elements for the improvement of food security (SDG 2) and the reduction of inequalities (SDG 10).

viii. **Identify and implement additional policies in other sectors**, especially to improve the achievement of SDGs with remote connections to agriculture such as SDG 3 (Good Health and Well-being), and also to further improve the achievement of SDGs with close connections to agriculture such as SDG 2 (Zero Hunger). Necessary policies involve interventions in areas such as education, health, infrastructure, distribution policies, renewable energy and governance. Further, the analysis reveals the need for additional interventions to prevent negative effects from GDP growth (caused by agroecological interventions) such as further promoting material consumption efficiency and recycling in other (production) sectors to ensure sustainable consumption and production patterns (SDG 12).

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