Applying the nexus – meeting Ethiopia's development goals by addressing links between water, energy and food

Key findings

- Our work in the Upper Blue Nile basin shows that the two processes – agricultural transformation and energy transition – are interdependent and could be partly competitive. As agriculture becomes increasingly intensified it will require more energy. At the same time the energy system will, at least in the foreseeable future, continue to be largely supported by biomass, partly originating from croplands.
- Ethiopia appears to have hit a "biomass ceiling". The country currently uses approximately the same amount of biomass for food, fodder and fuel as grows there (i.e. primary productivity). This hinders agricultural production, threatens biodiversity and may in the long-term constrain Ethiopia's economic development. To unlock the full potential of agriculture and to protect biodiversity in ecosystems such as wetlands and forests, there is an urgent need to shift away from the use of traditional biomass for energy, and to reduce livestock grazing on croplands.
- Upstream water withdrawals for irrigation can reduce available water for meeting people's needs, maintaining healthy ecosystems, and for hydropower. However, if properly managed, upstream irrigation dams can buffer seasonal variations in water flow, providing more water during dry seasons. Different groups and ecosystems require water for different and sometimes competing purposes. Thus, there is a need for dialogue between all relevant stakeholders on how reservoirs operate, and on the rules that govern hydropower and irrigation dams.
- SEI's nexus toolkit (WEAP-LEAP) enabled joint learning between stakeholders from the agriculture, energy, water and environment sectors, such as planners, NGO's, and scientists. Stakeholders reviewed the quality of the data used in the toolkit, as well as its assumptions and results, and also ensured that the scenarios developed were relevant. In workshops, multi-stakeholder groups assessed the impact of the scenarios on stakeholders and ecosystems in the upper Blue Nile region of Ethiopia. The nexus toolkit produced results that take into account interlinkages between the agriculture and energy sectors, resource allocations, and environmental impacts.

Introduction

In an environment in which available water, land and energy are increasingly limited, there is a need to use these resources prudently and equitably in order to meet human aspirations. Whilst many millions of people lack basic human securities (i.e. food, energy and water), population growth, shifting consumption patterns and a changing climate result in additional pressures that degrade the resources on which people rely. A new approach is required that reconciles human securities with sustainable management of natural resources and ecosystems. This methodology has been coined a "nexus approach" (Bazilian et al., 2011; Hoff, 2011; Howells et al., 2013), and emphasizes the importance of human aspirations in resource allocation, and focuses on cross-sector interactions.

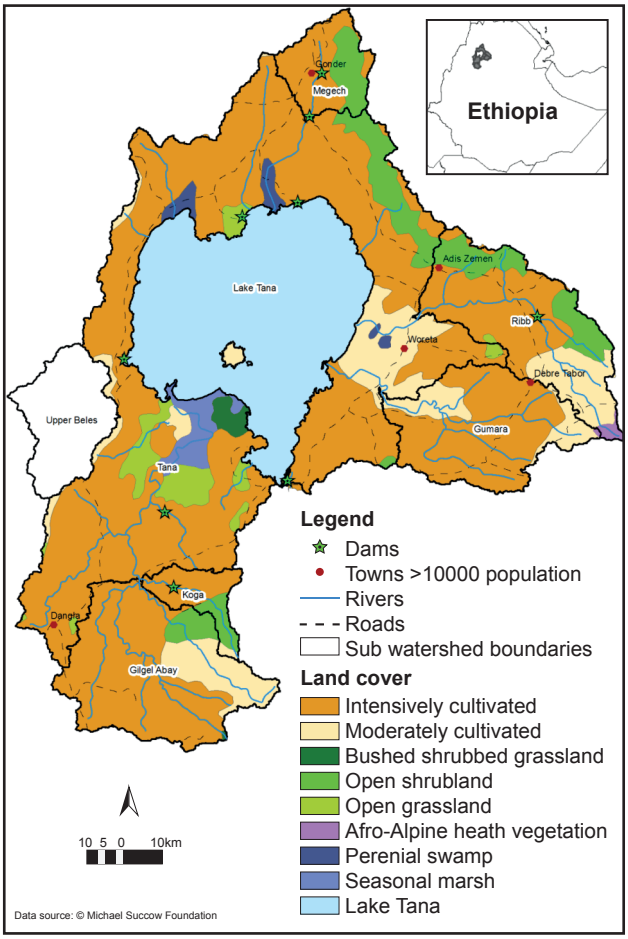
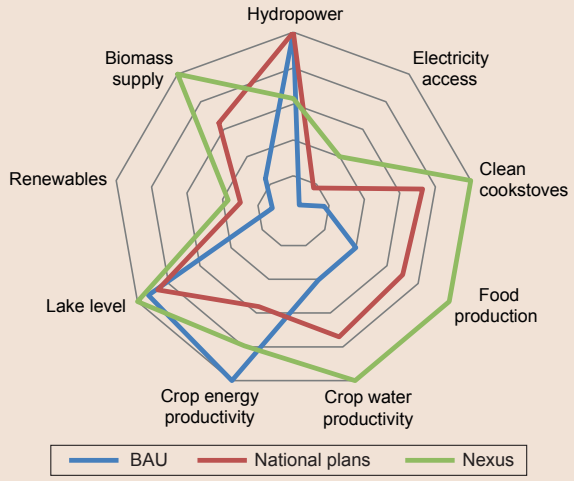


Figure 1: Land-use map of Lake Tana (Upper Beles) sub-basin
(Source: Michael Succow Foundation)

Although the nexus approach is relatively new, nexus-related activities, events, and publications are already globally prolific.[1] However, apart from a few cases (e.g. Hermann et al. 2012; Purkey et al. 2012; Welch et al. 2012), these activities have not been driven by genuine demand or based on a consistent analytical framework and nexus tools. Only this combination will allow the benefits of a nexus approach to be mapped and measured for practical use in policy and decision-making.

This brief summarizes the main findings from a collaborative project in the Lake Tana and Beles River basins of the upper Blue Nile in Ethiopia. The project supported the work of government planners and other stakeholders (Karlberg et al., forthcoming), and aimed to *improve food and energy security and environmental sustainability by assessing the impact of different development pathways on the food, energy and environment nexus.* Specifically, the project included the following objectives:

1 A comprehensive list of these activities, events and publications can be found on the Nexus Resource Platform maintained by the German Government. See www.water-energy-food.org.



Note: Explanation of the nine indicators:

Food indicators: *food production* refers to total food produced in the Lake Tana region; *crop water productivity* is the yields per unit of water consumed; *crop energy productivity* is the yield per unit of energy spent in the production process.

Energy indicators: *hydropower* is the total production of hydropower; *electricity access* is the total amount of the population connected to an electrical grid; *clean cookstoves* is the penetration of the cookstoves replacement programme.

Environment indicators: *biomass supply* refers to the ratio between biomass supply and biomass demand; *renewables* is the amount of non-wood renewables in the total energy supply; *lake level* refers to the amount of time that the lake is above its critical lowest level.

Figure 2: Visualization of WEAP-LEAP results: Levels of success in meeting the nine indicators for development in the three different development scenarios. The closer a line is to an indicator, the better the performance on it.

- To measure feedbacks and links between the agricultural and the energy sector, and to determine how these impact on the environment and stakeholders from the agriculture, energy, water and environment sectors in the upper Blue Nile region
- To develop a methodology for applying the SEI nexus toolkit in joint-learning processes with stakeholders, and
- To support policy-making in Ethiopia in the natural resource sector from the local to national scale.

We used the SEI nexus toolkit (WEAP-LEAP)[2] to compare the effects of different development pathways and interventions on different stakeholder groups and the environment. By using this toolkit, policy-makers and planners can identify and develop ways to improve food and energy security and support continued economic development, while sustainably managing natural resources and reducing negative environmental impacts, in line with Ethiopia's ambitious national policies (see below).

A nexus project in the Upper Blue Nile

Ethiopia has committed itself to reaching middle-income status by 2025 (MoFED 2010). To achieve this ambitious goal, the country has set a variety of targets for several sectors, including agriculture and energy. Following a decade of strong agricultural growth, the targets in Ethiopia's Growth and Transformation Plan (GTP) and the forthcoming Growth and Transformation Plan II (GTP II) cover a wide range of agricultural issues (including improved seeds, fertilizer, mechanization, irrigation), as well as energy production (e.g. hydropower), and conservation and land reclamation. For example, by 2025 Ethiopia aims to increase cultivable land by 13%, and irrigated land by more than 400%. With such a dramatic expansion (e.g. a 30% increase in productivity of various crops) Ethiopia's Ministry of Finance and Economic Development expects fertilizer use to increase by approximately 100% (MoFED 2010). Ethiopia's GTP also outlines a National Resource Conservation Plan that seeks, among other things, to rehabilitate land and increase forest cover. These conservation targets are further detailed in Ethiopia's Climate Resilient Green Economy Strategy (CRGE), which aims to combine economic development and sustainability (Federal Democratic Republic of Ethiopia, 2012).

These targets are achievable. But it is not clear whether the possible conflicts and negative impacts of pursuing them have been considered. For example, allocating additional water for irrigation may compromise hydroelectric power generation, and conflicts such as this can impact on human welfare and the local environment. A nexus approach could help to achieve GTP targets by taking into account links between sectors.

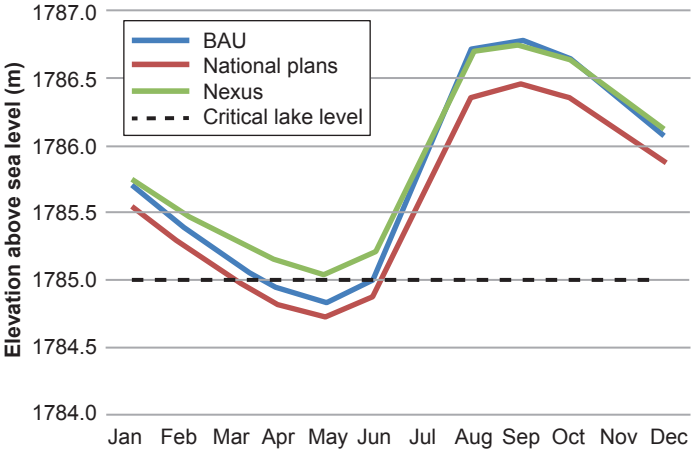
Using the nexus toolkit to support food, energy and environmental planning

SEI's nexus toolkit integrates two software tools, the Water Evaluation and Planning (WEAP) system (Yates et al. 2005a, 2005b), and the Long-range Energy Alternatives Planning (LEAP) system (Heaps 2012). We used these tools to assess the impacts of scenarios in which resources for food and energy production are allocated differently, and also to identify impacts on the environment and links between sectors.

The Lake Tana/Beles area illustrates many of the trade-offs implicit in the national targets (see Figure 1). The area is a culturally important part of Ethiopia. Four large irrigation dams are in various stages of construction in highland areas where farmers practice small-scale rain-fed farming. A large hydropower plant was recently constructed using Lake Tana as a reservoir, redirecting the water to the Beles River downstream. The lake itself supports fishing and tourism, and there are plans to designate it as a United Nations Biosphere Reserve because of its unique bird life and fish species (zur Heide 2012). Objectives for managing local land and watersheds include reducing soil erosion, land degradation, and siltation of watercourses and reservoirs, as well as increasing local storage of water for small-scale irrigation purposes and livestock for instance, and for maintaining wetlands and other ecosystems.

SEI, its project partners and stakeholders applied the nexus toolkit in the Lake Tana/Beles area to develop and analyze the outcomes of different development scenarios representing three development pathways from 2010 until 2030. To do this we used a story and simulation approach (Alcamo, 2001), in which narratives developed with stakeholders were translated

2 For more information on LEAP see: www.energycommunity.org. For more information on WEAP, see: www.weap21.org.



Scenario	Hydropower production (GWh)
BAU	1100
National plans	1100
Nexus	610

Figure 3: Average annual fluctuations in the Lake Tana water level (left) and average annual hydropower production (right) in the three scenarios.

into quantitative data and incorporated into the toolkit. We did this to identify links between sectors (e.g. energy requirements for agriculture) and stakeholders reviewed the assumptions and data use until the results were deemed credible.

The scenarios analyzed in the project are described below, along with their key features:

- *Business-as-usual scenario.* This scenario projects forward on the basis of today's patterns of land and water use and management.

- *National plans scenario (meeting the GTP and CRGE targets).* This scenario gives highest priority to water for food production and energy generation. It assumed that domestic energy demand per capita is reduced after the introduction of more efficient stoves and increases in connectivity to the national grid. Cattle are replaced by tractors, reducing the livestock population.

- *Nexus scenario (meeting the GTP and CRGE targets as well as resolving outstanding conflicts between sectors).* Under this scenario the highest priority for water is to maintain the level of Lake Tana. It is assumed that only sustainable amounts of crop residues are used for energy. Also, fodder is produced only as a by-product of crops produced for food and other purposes, while a bold electrification scheme reduces biomass demand in the energy sector.

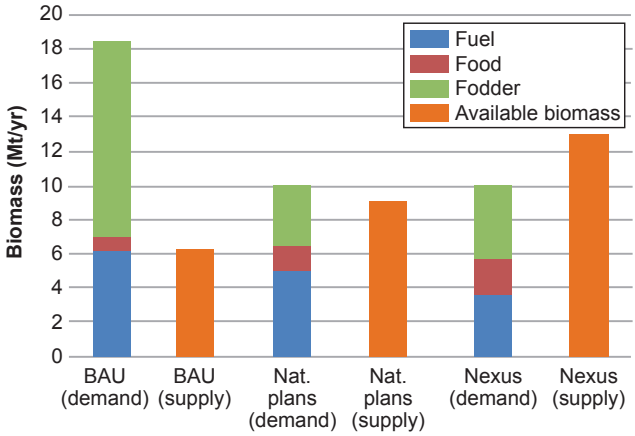


Figure 4: Biomass demand compared with available biomass (supply) in the region under the three scenarios

Results

Food and energy production and related environmental impacts differ substantially between the three development scenarios. Figure 2 illustrates these differences across nine variables pertaining to food, energy and environment.

Because the nexus scenario maximizes food production and prioritizes maintaining Lake Tana's water levels, hydropower production is substantially lower than under the other two scenarios. In contrast, the national plans scenario describes an intermediate level of food production coupled with high hydropower output from the Tana Beles station, seriously compromising the target to maintain water levels in Lake Tana. Finally, continuing along a business-as-usual path reduces per capita food production compared to current levels because of rapid population growth. Not only does total food and energy production vary between the three scenarios, resource-use efficiency also varies in the production of these commodities. Broadly, the nexus scenario receives a high rating for the indicators compared with the other two scenarios, except in terms of hydropower production and crop energy productivity.

Lake Tana's water levels affect maritime navigation, the fisheries industry, the *Negede* people (whose livelihoods are based around making boats and baskets from papyrus), the tourism industry, and not least the health of the lake's ecosystem. A critical minimum level for navigation is defined as 1785 meters above sea level (zur Heide, 2012). In the BAU scenario, the lake is below its critical level for approximately two months per year, due to withdrawals of water upstream and regulation of the lake's outflows for hydropower generation. This period increases to three months in the national plans scenario (Fig. 3), due to projected upstream irrigation developments. In this scenario the lower water availability for hydropower production is compensated for by allowing a larger draw-down of Lake Tana's water during the dry season. On the other hand, the nexus scenario assigned the highest priority to maintaining the lake level above the critical level, which significantly reduces hydropower production.

Biomass is required for fuel, food production and livestock farming. In the BAU scenario, the predicted demand for biomass is more than double the amount of biomass that is produced in the study area, which is untenable (without relying on substantial imports). Compared with the BAU scenario, the national plans scenario assumes higher crop productivity, while assuming lower demands for fuel and fodder. Therefore,

Policy recommendations

- The national plans of Ethiopia specify ambitious development and environment targets, but these targets could be even more ambitious. Implementation of the targets will of course also be critical.
- As Ethiopia reaches its biomass ceiling, planners need to reassess how biomass is used to ensure that it is used productively. Specifically, rural electrification schemes can have a big impact on biomass use. There is also a need to rethink fodder production for livestock, as well as the size of the livestock sector as a whole.
- As water resources become more regulated, there is a need for more detailed planning for water resources management, including processes for involving multi-stakeholder groups.
- Sustainability indicators such as environmental flow requirements and the sustainable outtake of biomass need to be defined in order to guide the planning process.
- Policies on natural resources should prioritize forums in which stakeholders from different sectors can engage in dialogue.

the net use of biomass is more or less the same as the annual increase in new biomass. In our nexus scenario, the demand for biomass for fuel is lower compared with the national plans scenario, and also allocates areas of cropland for producing fodder, thus indirectly reducing the potential for food production. Despite the latter, improved soil conditions enable higher productivity, making the nexus scenario the only one with higher total annual biomass production than biomass use.

Conclusions

Through the upper Blue Nile project, the SEI nexus toolkit helps planners at national and basin levels to better understand the complex relationships between different resource sectors. The project has revealed links between energy and agriculture in terms of water and biomass use, as well as a number of resource-use issues that must be addressed in order to achieve Ethiopia's planned transformation in the agricultural sector, while at the same time supporting energy transitions. Together, the nexus approach and the nexus toolkit provide insights that can empower Ethiopia's planners to achieve their sustainability objectives as the country progresses towards its economic development vision.

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