WaterPIP

Water Productivity Improvement in Practice

Integrated Assessment Framework for National Policies related to Agricultural Water Management

Framework description and application on a hypothetical case study

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Acronyms

EOS	End of Season
ET	Evapotranspiration
SOS	Start of Season
WaPOR	Water Productivity through Open access of Remotely derived data

1 Introduction

Water is becoming increasingly scarce. The largest water consumer worldwide is agriculture, which consumes around 70% of the total freshwater withdrawals with relatively low economic returns per unit of water consumed (Scheierling & Treguer, 2018). Water demand from other economic sectors with higher economic returns per unit of water consumed is also increasing, leading to greater competition for water. Growing population and rising meat consumption have already and will continue to increase the demand for food and thus agricultural products. Global agricultural food demand is expected to grow by 70% by 2050 (Scheierling & Treguer, 2018). As such, blue water use is estimated to increase by 65% between 2010 and 2050 (Springmann et al. 2018). In addition to these growing demands, climate change is in many instances expected to further impact available freshwater resources and water demand.

Existing policies around agricultural water management most commonly focus on increases in water use efficiency and water productivity (i.e., more crop per drop) in order to manage the trade-offs between increased food production and water conservation or reallocation of water. Various authors have already highlighted that "maximising agricultural water productivity" as a policy recommendation is not helpful due to different patterns of water use in different agro-climate zones (Amarasinghe and Smakthin 2014) and other farm-level factors, like market access and nutrients, that influence farmers' decisions (Wichelns, 2014).

Moreover, at a policy-making stage, advocating for maximizing agricultural water productivity and increasing the 'crop per drop' are limiting the complex goals and objectives of agricultural water management while also obscuring complex decision-making processes of balancing multiple socio-economic objectives of national development strategies (such as increasing employment, environmental sustainability, and ensuring food security). As such, discussions on water productivity should move beyond the narrow approach of 'more crop per drop' (Molden, 2007; Scheierling and Tréguer, 2018). A more holistic understanding of the value of water is necessary to assess the trade-offs between agricultural developments and reallocation of water. Agricultural water management should take into consideration agriculture's context-specific and multiple functions, including 'ensuring food security, reducing poverty and conserving ecosystem integrity' (p. 19, Molden, 2007).

Therefore, to assess national policies regarding water management, a broader set of criteria needs to be considered than bio-physical water productivity. Many factors will play a role in this decision-making process, such as employment generation, energy blending targets, poverty alleviation, and food sovereignty. These are closely related to geopolitical considerations, such as the willingness to become dependent on the import of staple crops (and therefore also become dependent on export trade bans and price spikes). In this line, the Integrated Assessment Framework was developed not to set priorities or resolve trade-off among such factors, but to make decisions about water management and allocation and their impacts explicit, deliberate and conscious.

The aim of this report is threefold. Firstly, to present the Integrated Assessment Framework that can make explicit how different agricultural development strategies score against various technical, economic and social indicators, with the ultimate goal of providing a holistic understanding of development strategies and their (inherent) trade-offs (Section 2). Secondly, to methodologically test and apply the Integrated Assessment Framework on a hypothetical case of two agricultural development strategies; the hypothetical horizontal expansion strategy and the hypothetical vertical expansion strategy (Section 3). And thirdly, to define the data requirements for the real-life application of the framework (Section 4). The report discusses the strengths and weaknesses of the approach taken and final conclusions are drawn (section 5).

2 Integrated Assessment Framework

In line with the approach that advocates for recognizing agriculture, and thus agricultural water use, as a multi-functional system (Susanne M. & Treguer O, 2018; IWMI, 2007), the Integrated Assessment Framework was developed. The basis of the Integrated Assessment Framework is to understand agricultural water demand as a demand derived from policy objectives and to incorporate such policy objectives in agricultural water management discussions. For example, national objectives might define and promote the cultivation of strategic crops in order to either satisfy the food needs of the country (usually staple crops) or obtain cash crops to obtain economic benefits and improve the trade balance of the country. These considerations are policy targets that have implications for agricultural water management and thus are directly linked to agricultural water management.

For the application of the Integrated Assessment Framework, the policy targets as well as the agricultural development strategies that are used to meet these targets are firstly delineated at national level through water and agricultural policy reviews[1]. Examples of these agricultural development strategies are the promotion of commercial farming versus the small-scale subsistence farming and the promotion of food exports versus the domestic consumption of food production. With the Integrated Assessment Framework, each agricultural development strategy is scored on the following indicators; biophysical water productivity, land productivity, economic water productivity, food security, food self-sufficiency, employment and environmental sustainability. The scores of these strategies on the various indicators are then plotted in a spider diagram, facilitating a quick visual scan of how the different agricultural development strategies are assessed against a number of indicators.

It should be pointed out that the scores of the various indicators and their explanations are highly dependent on the specific data, evidence and/or assumptions that are made by the individuals that apply the framework. As such, different stakeholders provide different scores and explanations for the agricultural development strategies, making different sides of the story visible. For this reason, the scores of the different agricultural development strategies are to be discussed and thus the Integrated Assessment Framework provides a policy dialogue support tool. The scores on the indicators provide a basis for dialogues with experts, policy-makers and local stakeholders. This will make the various implications of alternative agricultural development strategies more explicit.

In the following sections, the indicators of the Integrated Assessment Framework are discussed. Table 2–1 shows the brief explanation of each indicator. Due to some degree of complexity regarding the interconnections between the biophysical water productivity and the land productivity, these two indicators are discussed in greater detail.

Indicator 1 – Biophysical Water Productivity & Indicator 2 – Land Productivity

Biophysical water productivity refers to either biomass production or yield production for each unit of agricultural water consumed (usually through evapotranspiration, ET). Since there is a linear relation between water consumption and biomass production, the higher the agricultural water consumption, the higher the biomass production. In addition, the biomass water productivity is stable under the same fertility levels. Looking at the yield production function (Error! Reference source not found.), having water as the only limiting factor, the point of maximum water productivity (AW_{MAX}, Y_2, in Error! Reference source not found.) is different than the point of maximum land productivity (AW'_{MAX}, Y_{MAX} in Error! Reference source not found.). What this signifies is that maximum water productivity and land productivity cannot occur simultaneously (Wichelns, 2014).

[1] For the methodology of how to conduct a policy review see Christoforidou, Seijger & Hellegers, 2020

Table 2–1 - Indicator of the Integrated Assessment Framework

Indicator	Explanation
1. Biophysical water productivity (Molden et al., 2010; Wichelns, 2014; Halsema & Vincent, 2012)	Relation between either yield or biomass production (tons) and water use (evapotranspiration) or water transpired (transpiration)
2. Land productivity	Relation between yield or biomass production (tons) and agricultural land (ha)
3. Economic water productivity (Molden et al., 2010)	Relation between economic value obtained from yield ($) and water consumed (evapotranspiration). The obtained economic value of agricultural production depends on the buyer of the product and/or the final market (farm-gate, local market, export market price)
4. Food security (Pinstrup-Andersen, 2009)	The access for all people at all times to enough food for a healthy, active life. Access to food relates to the physical availability of food and the buying power to purchase food. As such, the higher the quantity of locally produced food and/or the economic returns from exported goods, the higher the degree of food security.
5. Food self-sufficiency (Pinstrup-Andersen, 2009)	Ability to meet food needs from domestic production rather than by food imports (particularly for staple food crops)
6. Employment (Christoforidou & Vos, 2020)	Absolute number of jobs generated or relation between number of jobs generated by the agricultural sector and water consumed (evapotranspiration). This indicator can be further delineated based on the social group that it is aspired to be empowered; i.e., number of women. In relation to economic water productivity, this indicator can be further concentrated on the pro-poor economic water productivity; the wages of workers in relation to water consumed (evapotranspiration).
7. Environmental sustainability (Morelli, 2011)	Responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality. Issues to consider could be threats to natural wetlands, increasing salinity intrusion, decreasing availability of environmental flows, and unsustainable use of pesticides. This indicator is not only limited to water-related aspects but it can be expanded to other environmental considerations, such as protection of natural ecosystems and rainforests.

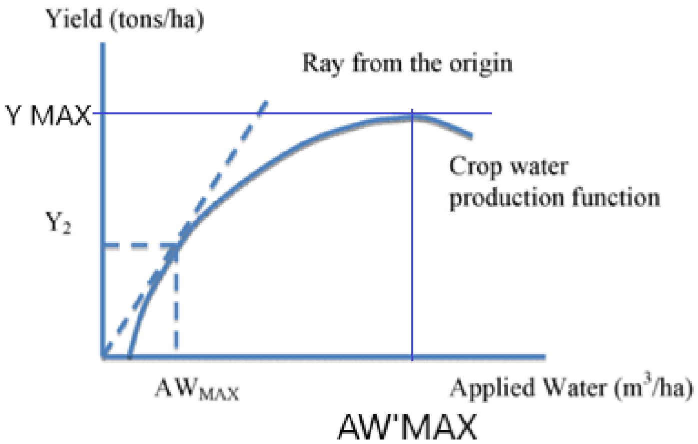

Figure 2-1 – Yield production function (adopted from: Wichelns, 2014)

3 Application of the Integrated Assessment Framework on a Hypothetical Case

In order to test the framework, it was applied to a hypothetical case under two different hypothetical agricultural development strategies: the hypothetical horizontal strategy and the hypothetical vertical expansion strategy. The hypothetical horizontal strategy focuses on expanding agricultural land and cultivation in areas that were previously used for purposes other than farming. The hypothetical vertical strategy focuses on increases of agricultural production within existing agricultural areas. These two strategies are commonly discussed for agricultural development and can take place simultaneously.

The application of these strategies is context-specific, contributing to different policy objectives and affecting differently the different indicators of the framework. In the following section, each strategy is briefly discussed under different contexts, then the specific interpretation that is used for the hypothetical application of the framework is defined and an indicative example is given. It should be noted that this is just an interpretation of possible characteristics and consequences of these strategies (hence the hypothetical application of the framework). Other interpretations of the strategies can also take place. As such, this report is not exhaustive in how the two strategies can be interpreted and/or implemented but rather shows how the framework can capture their differences at different levels.

3.1 Horizontal Expansion

The horizontal expansion strategy considers that a plot of uncultivated land is taken up for agricultural purposes. As such, horizontal expansion changes the land use of an area. This change might have either positive or negative impacts in the different indicators of the framework, which may also change depending on the perspective in which the assessment is done. Thus, it is important to acknowledge the conditions of the previous land use. In cases that horizontal expansion strategy is adopted in desert areas where water is scarce, with limited or no rainfall, additional irrigation water is necessary. In this context, horizontal expansion requires additional blue water use in agriculture that could possibly be sourced from groundwater, surface water or water savings from efficiency gains. Overall, this increases the water demand and thus decreases groundwater sustainability or environmental flows. This negatively affects the indicator of environmental sustainability. The horizontal expansion strategy might also be adopted under rainfed conditions and green water use. In cases where new cultivations involve fruit trees with deep routing system (such as olives) in areas where desertification process are taking place, the surface runoff will decrease due to increased infiltration and soil erosion will be reduced. Another case of rainfed horizontal expansion regards new agricultural areas in natural ecosystems, forests and rainforests. In these cases, ecosystems are degraded and lost and thus the environmental sustainability indicator is negatively affected. In all cases, food production is increased in absolute terms and thus the indicators related to food security/food self-sufficiency are positively impacted. Similarly, since more food is produced, it is expected that employment is increased in the agricultural value chain.

3.1.1 Hypothetical Horizontal Expansion Strategy

In this interpretation of the horizontal expansion strategy, land use is changed from a natural rainforest ecosystem to agricultural land. As such, horizontal expansion comes at the expense of rainforest protection. Agricultural production uses mainly rainfall water (green water) that is available in the area. The local water balance is also changed. Rainforests generally consume and help infiltrate great quantities of water. After the implementation of the horizontal expansion in the rainforest area, less water will be consumed and infiltrated, increasing the surface runoff and reducing the groundwater recharge. Agricultural production in this interpretation is focused on exporting to other countries and thus contributing to higher food security.

Example: Soybean Expansion in Brazil

An example of horizontal expansion strategy is the expansion of soybean cultivations in the Brazilian Amazon. Brazil includes the greatest part of the Amazon rainforest. In the beginning of 2000, deforestation took place in the Brazilian Amazon in order to, among others, expand the area of cultivation for soy bean. Between 2001 and 2006, 1 million hectares of rainforest was deforested for soy cultivation[2]. Figure 3-1 shows the deforestation per year in relation to the annual soy production, with the highest deforestation rate to take place during 2004. Most of the soy cultivations in Brazil are exported (Nepstad & Simada, 2018). For 2019, Brazil was the largest soybean supplier for the Netherlands, as 44% of all imported soybeans came from Brazil[3]. During 2006, the Soy Moratorium agreement decreased deforestation in the Amazon. After its implementation, around 99% of the soy cultivation in Brazil was grown in already cleared land in the Amazon. However, since 2012 deforestation rate has increased (Nepstad & Simada, 2018) with soy production steadily rising.

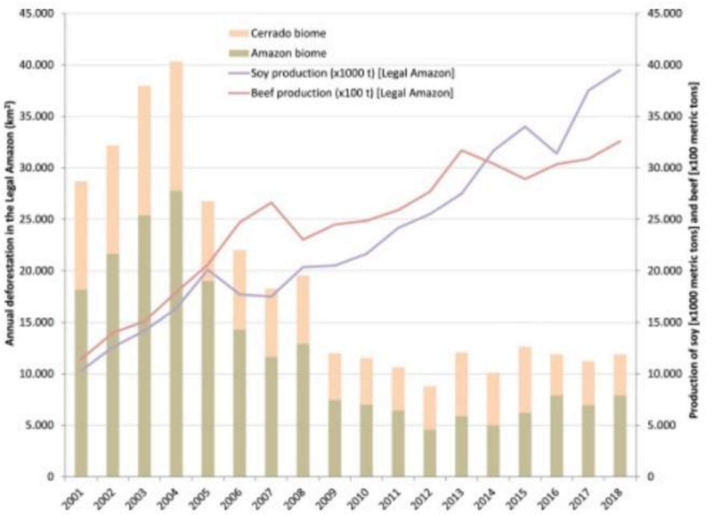

Figure 3-1 - Deforestation (km^2/year) in the Amazon (green bar) and Cerrado (yellow bar) biomes of the legal Amazon states and the annual production of soy (purple line) and beef (red line) (Adopted from: Stabile et. al., 2020)

3.2 Vertical Expansion

The vertical expansion strategy considers that a plot of already cultivated land is managed differently in order to produce more yield. The focus of the strategy is to maximize production per unit of land. Such yield improvements can take place either through better agronomic management (better varieties, timing and duration of irrigation, soil fertility levels, pesticide use etc.), through increases in blue or green water use or using both of the ways mentioned above. Food production is also increased. As such, food security and/or food self-sufficiency increases, depending on the type of crop and the market that is sold. In cases of rainfed agriculture, providing that enough green water is available, soil fertility improvements can significantly increase yield production by shifting the yield production function. However, extensive use of fertilizers and pesticides might affect natural ecosystems and pollute the groundwater tables. As such,

[2] Source: https://news.wisc.edu/study-shows-brazils-soy-moratorium-still-needed-to-preserve-amazon/
[3] Source: https://www.cbs.nl/en-gb/news/2020/40/soybean-imports-from-brazil-up-by-40-percent#:~:text=Brazil%20largest%20soybean%20supplier%20for,this%20period%20it%20was%20Brazil.

issues of environmental sustainability are important. In irrigated agriculture soil fertility levels are usually optimally managed, and thus increases on yield are taking place through increases in water consumption. In this case, the yield production function is the same as before and increases are due to moves along the curve. As such, additional blue water might be used and thus lead to increased water demand.

3.2.1 Hypothetical Vertical Expansion Strategy

In this interpretation of the vertical expansion strategy, increases of yield production are taking place due to better fertility levels. This way, yield increases under the same water consumption. As such, there are clear water productivity gains. However, application of fertilizers has caused significant environmental issues, affecting the environmental sustainability indicator. Agricultural production in this hypothetical vertical expansion strategy is focused on staple crop cultivation (wheat, potatoes) for domestic consumption and thus contributing to higher food self-sufficiency.

Example: Intensification of agricultural production in the Netherlands

An example of vertical expansion strategy is the intensification of agricultural production in the Netherlands. The Netherlands have increased significantly their land productivity since 1950. As seen in Figure 3-2, crop yields for potatoes and sugar beet almost doubled during this period. For vegetables, the crop yields increased even more; cucumber increases more than eight times. These increases of crop yields were mainly due to the intensive use of fertilizers and pesticides as well as the adoption of innovations at farm level, such as the use of domestic natural gas resources for maintaining more favorable condition in greenhouses[4]. However, the intensive use of fertilizers is associated with nitrogen and phosphorus losses, which leach into streams and groundwater reservoirs, and thus causing widespread pollution (Van Gaalen et al., 2015).

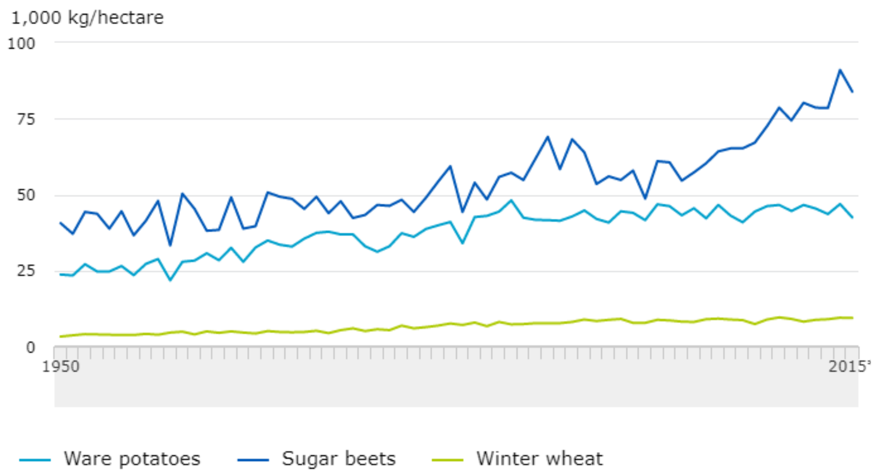

Figure 3-2 - Arable Crop Yields for ware potatoes (light blue line), sugar beets (dark blue line) and winter wheat (green line) in the Netherlands between 1950-2015 (Source: CBS, retrieved from: https://www.cbs.nl/en-gb/news/2017/05/agricultural-production-in-the-period-1950-2015)

3.3 Scoring of the Hypothetical Agricultural Development Strategies

To sum up on the two hypothetical expansion strategies, the specific characteristics of the strategies are presented in Table 3–1. Table 3–1 sets the basis for the argumentation of the application of the Integrated Assessment Framework in the hypothetical case.

[4] Source: https://www.cbs.nl/en-gb/news/2017/05/agricultural-production-in-the-period-1950-2015

Table 3–1 – Specific Characteristics of Hypothetical Horizontal and Vertical Expansion strategies

	Hypothetical Horizontal Expansion Strategy	Hypothetical Vertical Expansion Strategy
Objective	Increasing cultivated lands	Maximizing land productivity
Crops	Soybeans	Wheat, potatoes
Markets	Exports, cash crops	Local, staples
Environmental Impacts	Rainforest destruction Destruction of environmental services from the rainforest	Heavy use of fertilizers, leading to pollution
Food Security Considerations	More food is produced for exports	More food is produced for domestic consumption

Following, each indicator of the framework is assessed in comparison for the two hypothetical expansion strategies. For the biophysical water productivity and the land productivity indicator, the yield production is used.

Indicator 1 – Biophysical Water Productivity & Indicator 2 – Land Productivity

Considering that the yield production function of the two different agricultural systems is the same after the implementation of the interventions (expanding to previously non-cultivated lands and applying fertilizers in the already cultivated lands), the vertical expansion strategy is expected to increase its agricultural water consumption (move along the yield production function) in order to meet its goal of maximizing land productivity. This way, vertical expansion strategy will score lower in biophysical water productivity and higher in land productivity compared to horizontal expansion strategy.

Indicator 3 – Economic Water Productivity

As discussed, the hypothetical horizontal and vertical expansion strategy are focused on different crops, with the former strategy focusing on soybean, a cash-crop, while the latter strategy focuses on staple crops, such as wheat and potatoes. Cash crops have a higher economic return compared to staple crops. Additionally, export prices are also assumed to be higher compared to domestic ones. In terms of water consumption requirements for the crops cultivated under the two hypothetical strategies, soybean and wheat have around the same water needs[5]. As such, the economic water productivity of the hypothetical horizontal strategy and the cultivation of soybean is higher compared to the hypothetical vertical strategy and the cultivation of wheat.

Indicator 4 – Food Security

The hypothetical horizontal strategy refers to export markets and cash crops (soybean) while the hypothetical vertical strategy refers to domestic consumption and staple crop (wheat). Through exports, higher economic benefits are obtained that increase the level of food security. As such, the hypothetical horizontal strategy scores higher in food security compared to the hypothetical vertical expansion strategy.

Indicator 5 – Food Self-sufficiency

Under the hypothetical vertical strategy, staple crops (wheat) are produced while under the hypothetical horizontal strategy, cash crops (soybean) are produced. Staple crops are essential for directly meeting the

[5] Source: http://www.fao.org/3/s2022e/s2022e02.htm

caloric needs of a population and ensuring domestic food consumption. Hence, the hypothetical vertical strategy scores higher in food self-sufficiency compared to the hypothetical horizontal expansion strategy.

Indicator 6 – Employment

The hypothetical horizontal strategy is creating new agricultural lands that go hand in hand with new job opportunities both at the farm level and the agriculture value chain. Under the hypothetical vertical strategy, job opportunities will increase only in the agricultural value chain due to the increase in the agricultural output will be created but not at farm level. Therefore, hypothetical horizontal strategy scores higher in the employment indicator compared to the hypothetical vertical strategy.

Indicator 7 – Environmental Sustainability

The hypothetical horizontal expansion strategy involves changing the land use type from a natural ecosystem to an agricultural area. This has significant environmental impacts as deforestation takes place and the local water balance is expected to change drastically. Regarding the hypothetical vertical strategy, intensive fertilizer and pesticide use has resulted in groundwater pollution. In both cases the environmental impacts of the interventions are significant. Due to the high significance of the rainforests for issues of biodiversity and climate change, it is considered that the hypothetical vertical strategy scores higher in environmental sustainability indicator compared to the hypothetical horizontal strategy. However, the scores are low for both of the strategies.

Based on these considerations, the relative scoring of each strategy was done to portray the trade-offs between the strategies under each indicator. The scale for scoring ranges from 1 to 5, with 1 being the lowest and 5 being the highest. Table 3–2 shows the application of the Integrated Assessment Framework and the scoring of the hypothetical horizontal and vertical expansion strategies. Figure 3-3 shows the visualization of the application of the Integrated Assessment Framework in the hypothetical case through a spider diagram.

Table 3–2 – Application of the Integrated Assessment Framework (scoring of the hypothetical horizontal and vertical expansion strategies)

Indicator	Hypothetical Horizontal Expansion	Hypothetical Vertical Expansion	Justification of Scoring
1. Biophysical water productivity (kg biomass or yield/m^3)	3	2	The hypothetical vertical strategy aims to maximize land production, which can only be maximized under decreased (lower than optimal) biophysical water productivity. Therefore, biophysical water productivity is lower in the vertical expansion than the horizontal expansion.
2. Land productivity (kg biomass or yield/ha)	3	4	The hypothetical vertical strategy aims to maximize land production. Thus, hypothetical vertical strategy scores higher than hypothetical horizontal strategy in this indicator.
3. Economic water productivity ($/$m^3$)	5	3	Water consumption of both strategies are at the same level. Hypothetical horizontal strategy focuses on economic important crops and exports, and therefore scores higher than the hypothetical vertical strategy.

Indicator	Hypothetical Horizontal Expansion	Hypothetical Vertical Expansion	Justification of Scoring
4. Food security	5	4	The buying power to purchase food increases more under the hypothetical horizontal strategy. Hence, hypothetical horizontal expansion strategy scores higher in food security compared to hypothetical vertical strategy.
5. Food self-sufficiency	3	4	Although production increases with hypothetical horizontal strategy, the production is largely for the export market. The hypothetical vertical expansion strategy is for production to meet domestic staple food needs. Therefore, hypothetical vertical strategy scores higher on food self-sufficiency compared to hypothetical horizontal strategy.
6. Employment	4	3	Extra employment is generated with the cultivation of new lands at the field. Both strategies increase agricultural production and thus employment opportunities in the agricultural value chain.
7. Environmental sustainability	1	2	Both strategies are causing environmental degradation (deforestation and groundwater pollution). As such, both strategies score low in this indicator. The destruction of rainforest is assessed highly environmental unfriendly and thus hypothetical horizontal strategy scores lower compared to hypothetical vertical strategy.

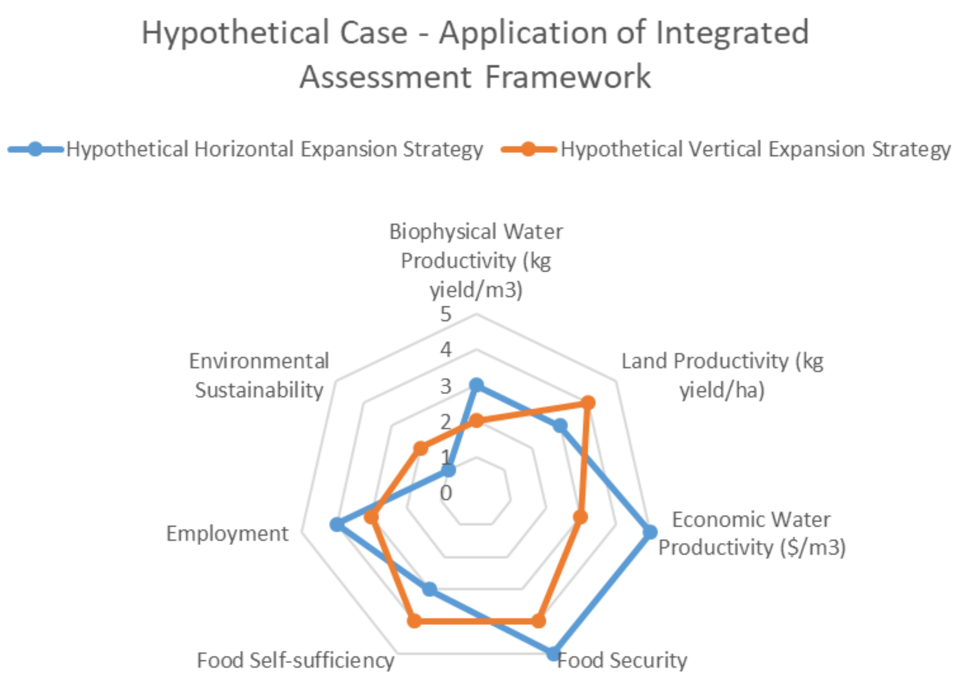

Figure 3-3 - Desktop application of the Integrated Assessment Framework using a spider diagram – Hypothetical case of Hypothetical Horizontal and Vertical expansion strategy

3.4 Analysis

Although the two strategies are compared as two distinct strategies, it should be noted that both can be pursued at the same time. Nonetheless, trade-offs emerge as the spider diagram offers a quick graphic overview of how the strategies score against each other on a set of indicators. In the desktop application of the Integrated Assessment Framework for the hypothetical case, a very clear trade-off is already presenting itself. The hypothetical horizontal strategy results in economically profitable agriculture that scores high on crop and economic water productivity but has significant environmental impacts. On the other side, the hypothetical vertical strategy aims at increasing its land productivity on existing areas, with no increases in the number of jobs generated, but with a higher environmental sustainability compared to the hypothetical horizontal strategy. As such, the trade-offs of the two hypothetical agricultural development strategies regard the high economic benefits, employment generation and increased water productivity against environmental sustainability issues.

4 Data Requirements

This hypothetical case is not specifically related to particular real-life cases, despite the examples of the agricultural developments in the Brazilian Amazon and the agricultural intensification in the Netherlands. As such, no concrete evidence and data were used. Rather, the scoring and explanations of the two hypothetical agricultural development strategies were highly dependent on the assumption of the authors of this report. However, in real-life applications of the Integrated Assessment Framework, data are essential to quantify retrospectively the impact of different agricultural development strategies on the indicators and support claims and future interventions. Table 4–1 shows the required data for each indicator.

The majority of the data requirements regard the socio-economic issues of the specific areas that the different agricultural development strategies are taking place (crop type, price of product, market sold to, net income of landowner and daily wages of laborers). These data can be either derived from field data and local surveys from farmers or from secondary sources (literature, FAOSTAT, etc.). Yield production values should also be considered through field data, as WaPOR cannot yet provide reliable insights on this variable. Regarding data for ET and biomass production, these can be derived from local water balance methods, field measurements and simulations which are normally costly and time consuming. Another possible source of data for ET and biomass is through satellite-based remote sensing dataset.

The Water Productivity through Open access of Remotely derived data (WaPOR) portal could potentially play a major role in acquiring such data. WaPOR can provide data from 2009 onwards for ET, biomass production, and water productivity at different levels of resolution – 250m at the continental scale, 100m at the national scale, and 30m at the sub-national scale. Currently, the portal has data available for Africa and the Middle East, with the intention being expanded to cover the globe in the upcoming years.

However, there are some limitations regarding the use of WaPOR data. WaPOR might be limited by pixel noise. Especially in smaller farm sizes where the field coverage of WaPOR satellite images is poor, there might be significant pixel noise. WaPOR data are limited in describing complex canopies such as orchards and thus WaPOR performs better in regions with field crops (Swelam et al., 2019). Moreover, it is crucial that a consistency check of the WaPOR data is done. Through this check, the linear relation between biomass and water consumption is assured, indicating whether WaPOR data are adequate to use. More information for the limitations of WaPOR are discussed in the “Lessons Learnt” report of the WaterPIP project (under development).

Table 4–1 - Data required for the real-life application of the Integrated Assessment Framework

Indicator	Data – Data Source
1. Biophysical water productivity	Biomass production (ton/ha/season, possibly WaPOR) Evapotranspiration (mm/season, possibly WaPOR) Yield production (ton/ha)
2. Land productivity	Biomass production (ton/ha/season) (possibly WaPOR) Agricultural Area (ha)
3. Economic water productivity	Net income of landowner ($/ha/season) - Price of product (depending on type of market, $/ton) - Production costs (farming and post-harvest, $/ha) - Labour costs (farming and post-harvest, $/ha) - Daily wages ($/day) Evapotranspiration (mm/season, possibly WaPOR)
4. Food security	Type of market (export or local market) Price of exported good ($/ton) Price of locally produced good ($/ton)
5. Food self-sufficiency	Crop type Type of market (export or local market)
6. Employment	Number of people working Labour input for farming (days/ha/season) Labour input for post-harvest (days/ton/season) Daily wages ($/day) Evapotranspiration (mm/season, possibly WaPOR)
7. Environmental sustainability	Water source used (surface, groundwater, treated wastewater) Additional water resource use (yes or no) Local environmental issues (yes or no, if yes, please name)

** Coarse indication of the start of season (SOS) and the end of season (EOS) are necessary from the field or secondary sources*

5 Discussion and Conclusion

The aim of this report was to present and test the Integrated Assessment Framework through a hypothetical case and share insights on the data requirements for the real-life application of the framework.

Testing the framework through the hypothetical horizontal and hypothetical vertical expansion strategies, its strength in making trade-offs between different agricultural development strategies explicit was illustrated. The main goal of the Integrated Assessment Framework is to facilitate a process where trade-offs between different options and choices are clear, thus making involved stakeholders and policymakers aware of the consequences of policy making choices. As such, the framework functions as a tool to understand water productivity beyond the notion of more 'crop per drop', opening up a wide range of aspects and policy objectives that are relevant for agricultural water management. This is one of the main benefits of this approach, as it leaves the weighting of importance of each indicator to the policy makers, enabling and facilitating a policy dialogue.

There are also limitations of the framework. First, the assumptions made in each case heavily influenced the scores of the strategies. In order to overcome this limitation, more data are essential to assess the different agricultural development strategies. Each indicator can be quantified and thus more easily compared between the different agricultural development strategies with field (primary or secondary) and/or WaPOR data. However, WaPOR data also have limitations. Some of these limitations regard the type of crops that WaPOR can handle and the size of the farm. WaPOR is also limited in producing reliable data for crop yield production, an indicator that is mostly appropriate to assess the productiveness of agricultural production. Biomass production is a related indicator of agricultural production. Biomass can be used as fodder and organic fertilizer but it cannot completely reflect the ways that water is turned into yield. The relation between biomass and yield production is dynamic and changes during the growing season. Agronomic aspects such as water and soil fertility stress might result in high biomass production but low crop yields. For example, water stress during the yield formation phase of the plant can significantly reduce yield while biomass is less influenced. Second, a limitation of the framework is that attributing scores to the indicators is subjective and depends on the person that is scoring. Third, the data requirements for the real-life application of the framework are very specific and thus might be difficult to obtain from the field.

The hypothetical case revealed that distinct agricultural development strategies can be compared with the Integrated Assessment Framework for productive agricultural water use. The backbone of the Framework and scoring procedure was explained in this report. As a next step, the Integrated Assessment Framework will be applied in policy dialogues for productive water use in Egypt and Jordan.

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