Valuing water for food security

How valuing water can contribute to optimal food security policy

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Onderzoek naar de mogelijkheden van het waarderen van water voor voedselzekerheidsbeleid. Het Food and Water Valuation Framework (FWVF) is ontwikkeld om het waterwaarderingsconcept te combineren met de voedselsysteembenadering. Dit kader wordt toegepast in vier casestudies om het voordeel ervan ten opzichte van bestaande concepten te beoordelen.

Research into the potential of valuing water for food security policies. The Food and Water Valuation Framework (FWVF) has been developed to combine the valuing water concept with the food system approach. This framework is applied in four case studies to assess its advantage over existing concepts.

Key words: Water, Food security, Valuation

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Contents

1 Introduction

Food systems and water resources are highly related. Water resources supply water as an essential input to food systems activities (FAO 2017) such as agricultural production, production in aquaculture, food processing and food consumption in achieving food security (SDG2). Conversely, food system activities also affect water resources by depletion of groundwater (Wada et al. 2012), non-point source pollution (nitrates, phosphates and pesticides) from agriculture (FAO and IMWI 2017) or discharges of untreated or poorly treated wastewater (Mateo-Sagasta et al. 2018). Population growth and dietary changes will require an increase in food production and will also expand the use of water and harmful side effects if business would continue as usual.

Water is an essential component of food production and better water management is necessary for achieving SDG2 (zero hunger) and SDG6 (clean water and sanitation). Therefore, not only agriculture but the entire food system must change towards a system with optimal use of natural resources. In many places in the world, more water is used than available locally and regionally (Wada et al. 2012). An allocation of water based upon the value of water for stakeholders (Dinar et al. 1997; Turner et al. 2004) will deal with trade-offs across water users: agriculture, industry, domestic use and nature (OECD 2015; OECD 2018). For safeguarding food security in the long run, however, the value of water in agriculture is only part of the story as there is also value derived from water in the other parts of the food system. To properly determine and quantify the value of water for food security, it is very important to link the food system (van Berkum et al. 2018) to water valuation concepts.

The Vision of the Dutch Ministry of Agriculture, Nature and Food quality (LNV), the client of this study, attaches importance to recognising ‘the value of food’, which is why LNV wants people to recognise better the value of water. To support the value of food and the value of water in decision-making, an analysis of the application of valuing water (ecological, economic and social) in the food system is warranted.

Overall objective and approach
The objective of this project is to support systemic change by valuing water in the food system by presenting concrete examples and possibilities where the application of the concept of valuing water in the food system has added value.

Based upon a case study approach, a conceptual framework is developed to link valuing water with the Food System Approach. Such a framework must be well-structured and transparent to enable the assessment of trade-offs in decision-making. The developed framework is tested in two (ex post) cases based upon literature where the value of water was estimated and applied in the decision-making process. The framework was subsequently used for preliminary policy advice in two (ex ante) ‘country’ cases, where both the value of water and food security play a role in the assessment of potential policies. This framework will be helpful for the ministry of LNV on how to better recognise the value of water in the food system, and to develop policies upon this knowledge.

The structure of the report is as follows. Chapter 2 first discusses a few relevant valuing water and food assessment initiatives. Contemporary concepts of frameworks on valuing water are presented and, based upon these concepts the Food-Water Valuation framework is presented. In Chapters 3 to 6 we present four case study applications of the framework. The final chapter discusses findings, conclusions and presents recommendations.

2 The Food-Water Valuation Framework

This chapter presents a brief overview of relevant valuing water and food assessment initiatives, describes water valuation frameworks and shows how their principles are linked with the Food System Approach and how these can be merged into the Food-Water Valuation Framework.

2.1 Relevant valuing water and food initiatives

Various international organisations are strategically addressing the present and future challenges associated with water and food. A brief description of two main initiatives (Valuing Water Initiative and OECD Triple Challenge) is given in this section as they are relevant within the context of developing a food-water valuation framework.

2.1.1 Valuing Water Initiative

In April 2016 the United Nations and the World Bank Group convened a High Level Panel on Water (HLPW) to provide the leadership required to champion a comprehensive, inclusive and collaborative way of developing and managing water resources, and improving water and sanitation related services (VWI, 2020). The Dutch Government is playing a key role in this initiative and aims to generate experience on how to sustainably, efficiently, and inclusively allocate and manage water resources and deliver and price water services.

In this context, the HLPW defined 5 Valuing Water Initiative (VWI) principles to value water (VWI, 2020):

1. Recognise and embrace water's multiple values to different groups and interests in all decisions affecting water
2. Reconcile values and build trust – conduct all processes to reconcile values in ways that are equitable, transparent and inclusive
3. Protect the sources, including watersheds, rivers, aquifers, associated ecosystems, and used water flows for current and future generations
4. Educate to empower – promote education and awareness among all stakeholders about the intrinsic value of water and its essential role in all aspects of life
5. Invest and innovate – ensure adequate investment in institutions, infrastructure, information and innovation to realise the many benefits derived from water and reduce risks.

VWI's framework proposes the adoption of a six-step approach.

1. Define your system – Whose values are at stake?
2. Determine the problem – What values are at stake?
3. Evaluate what needs to be achieved – How should the values be reconciled?
4. Map the current system dynamics – What leads to unsustainable collective behaviour?
5. Discuss the maturity of the initiatives and solutions so far – What initiatives are currently being rolled out and how do they contribute to systemic change?
6. Use the stakeholder matrix to decide what needs to be done – Who can or should do what to drive systemic change?

The first three steps in VWI's framework capture the five VWI principles, the latter three deal with the systemic change to generate better decisions based upon valuing water (VWI, 2020).

As the Valuing Water Initiative is looking for synergies with relevant other initiatives (not only focused on water), a link with the Food-Water Valuation Framework, developed in this study, is considered to be relevant.

The VWI principles are elaborated into a concept with guidelines how to apply the valuing water concept, to assess the value of water as a tool for better decision making. The VWI concept applies a water-system context, not a food-system context.

2.1.2 OECD Triple Challenge

OECD is working on defining policy priorities for the global food system as the world is facing a complex Triple Challenge (OECD, 2020):

1. Deliver safe and nutritious food to consumers, in sufficient quantities and at prices they can afford
2. Preserve natural resources while reducing greenhouse gas emissions and avoiding the destruction of valuable ecosystems and biodiversity and
3. Provide a livelihood to farmers and others in the food chain, and promote rural development.

The Triple Challenge provides a simplified organising framework for considering the most salient interactions. This Triple Challenge is visually presented in Figure 2.1, which shows that complex synergies or trade-offs across all three dimensions exist. For example, a reduction of meat consumption in developed countries could lead to improved public health and lower greenhouse gas emissions, but it would likely reduce livestock farmers' income in these countries if export opportunities for meat do not exist. As such a more holistic approach is required that would take into account all relevant synergies and trade-offs in designing the optimal policy mix (OECD, 2020). Identifying and valuing the trade-offs through consultation with different stakeholders is a main element in this challenge for defining optimal solutions. In this context, a systematic framework for identification and quantification of trade-offs as well as synergies would be helpful to define Triple Challenge solutions.

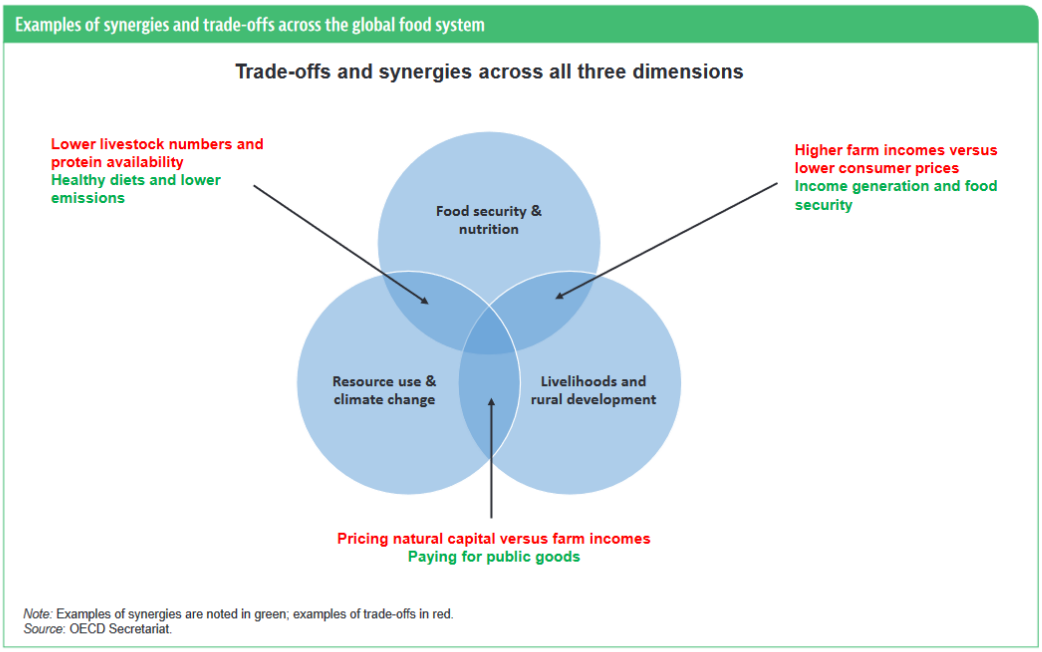

Figure 2.1 *Examples of synergies and trade-offs across the global food system*
Source: OECD (2019).

The Triple Challenge focuses on synergies and trade-offs across the global food system. It aims for a framework that incorporates the food system (and not agriculture alone); it does not focus on water valuation explicitly as an assessment tool. The concept of the Triple Challenge is not (yet) elaborated in an assessment framework.

2.2 Food System Approach

Food systems are highly complex systems, encompassing all the stages to feed the population: agricultural production, harvesting, packing, processing, transforming, marketing, consuming and disposing of food (UNEP 2016; van Berkum et al. 2018; FAO 2018). The food systems approach (FSA), see Figure 2.2, developed at Wageningen University and Research is an interdisciplinary conceptual framework for research and policy aimed at sustainable solutions for the sufficient supply of healthy food (van Berkum et al. 2018, see also Ingram 2011). With the FSA the drivers and outcomes of the food system can be analysed and the relationships between the different parts of the food system and the outcomes of activities within the system in socio-economic and environmental/climate terms explored. In particular, it includes primary production of agriculture, food processing, food transport, distribution of food and the diets of consumers. The food system outcomes include food security aspects like availability, but also access to food, food utilisation including food safety, and the stability of food security over time. The key section of the FSA is the Food System that includes the value chains and direct factors that define these value chains.

The FSA has a broader scope than water valuation or the market value chain approaches as it also includes the socio-economic and environmental drivers which have certain impacts on the food systems. Food systems thinking can contribute to an integrated approach that makes smart use of solutions at other levels of scale.

The FSA sheds light on non-linear processes in the food system, and on possible trade-offs between policy objectives. Systems thinking also broadens the perspective when seeking solutions for the root causes of problems such as poverty, malnutrition and climate change and may even be used for identifying future problems and solutions.

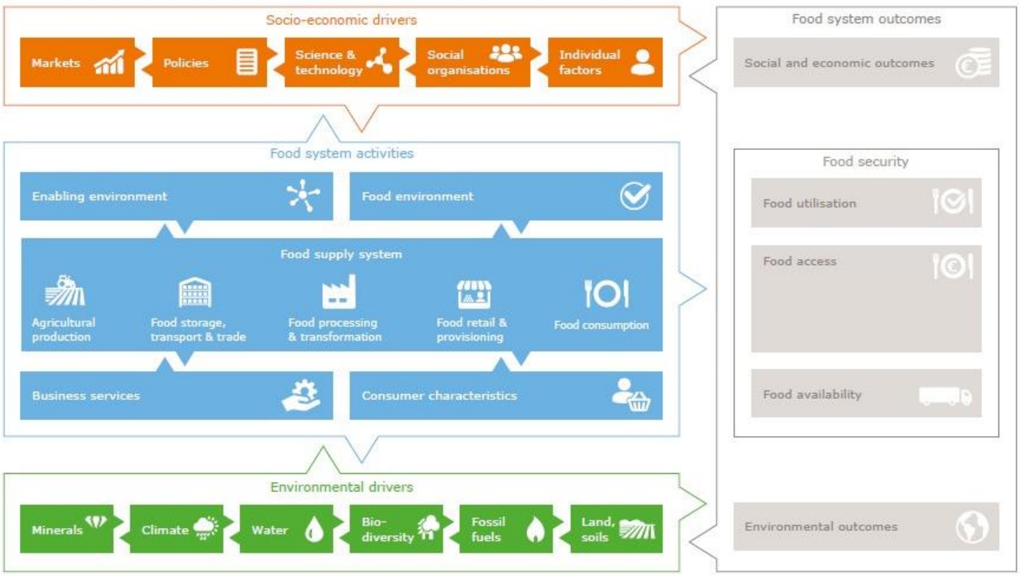

Figure 2.2 *The food system approach*
Source: van Berkum et al. (2018).

The FSA framework offers at least three benefits. First, it provides a checklist of topics that should at the very least be addressed when it comes to improving food security, certainly in relation to other policy objectives. Second, FSA helps to map the impact of environmental and climate changes on food security by pointing to the various vulnerabilities of the food system. In that sense the approach can contribute to the search for possibilities for strengthening the system’s resilience to climate changes. Third, it helps to determine the most limiting factors for achieving food security, and hence identify effective interventions aimed at improving food security. It has not been applied to water scarcity issues yet.

2.3 Overview of existing water valuation tools and frameworks

Water valuation in general is elaborated extensively in literature, to mention only a few of the most cited books and papers (Loomis and Young 2014; Young 1996; Turner et al. 2004; Birol et al. 2006; Brouwer et al. 2009; Booker et al. 2012; Ward and Michelsen 2002). Husain et al. (2007), Ward and Michelsen (2002) and Turner et al. (2004) valued water for agricultural use in a regional water system context as its value depends on alternative water uses. Many water valuation frameworks analyse the value of water within a watershed, which makes sense for agricultural purposes but not when food system outcomes such as food security are analysed. This report will enlarge the perspective of water valuation by incorporating the entire food system into the valuation.

This section describes two generic water valuation frameworks and one commonly used tool (Marginal Opportunity Cost), which are used for analysing benefits and costs to clarify trade-offs between alternatives. The purpose is to assess strengths and advantages of these frameworks that can be applied for the Food-Water Valuation Framework.

2.3.1 Valuation of Groundwater

The United States National Research Council (1997) developed a conceptual framework to evaluate trade-offs that occur whenever competing uses for groundwater resources exist (e.g. the use of groundwater for agriculture versus municipal purposes). The basis of the framework is built upon multidisciplinary integration of economic valuation approaches with hydrological and physical assessments as an integral way to solve the valuation problem (see Figure 2.3).

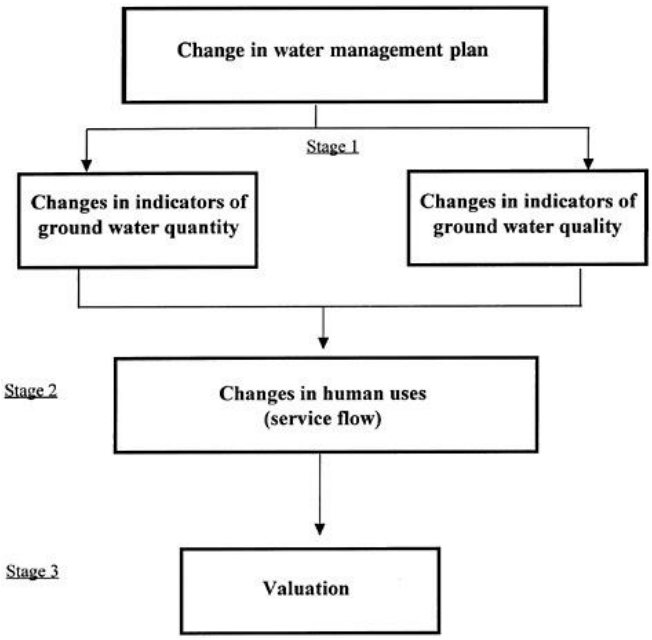

Figure 2.3 *Framework for trade-offs in ground water uses*
Source: United States National Research Council (1997).

The groundwater valuation framework is divided into three stages (Figure 2.3). The first stage involves an assessment of the current quality and quantity of groundwater resources in a particular area and how events or circumstances might alter the baseline quantity and/or quality. These changes could come from economic and social drivers, such as population growth, governmental policies, institutional reforms and adjusted or new production processes. This first stage assessment is particularly vested in the field of natural sciences (e.g. hydrology). The second stage maps changes in human water use associated with the changes described in stage 1. These changes in water use can be positive or negative. As an example: the installation of a new industrial area results in increased groundwater extraction. This generates several benefits such as increased employment and economic development. There may also be a number of negative effects such as increased damage at nearby houses (due to soil subsidence) or decreased water availability for nearby drinking water companies. The third stage quantifies the value of services and how these values are affected by changes in service flows (United States National Research Council 1997). This framework is quite generic for valuation of water in many situations within a water system, but does not include the food system in the analysis.

2.3.2 Marginal Opportunity Cost (MOC) Tool in water valuation

The Marginal Opportunity Cost (MOC) tool conceptualises and measures the effects of water depletion and degradation in economic terms as it measures full societal cost of an action or policy option (Turner et al. 2004). If the price of water is less than the MOC, then it shows whether the resource is overconsumed or overutilised. If the water price is higher than the MOC, then it shows the resource is being underconsumed or underutilised. As such, this tool provides an opportunity to establish sustainable water pricing, which may also include premiums to cover the costs associated with resource depletion.

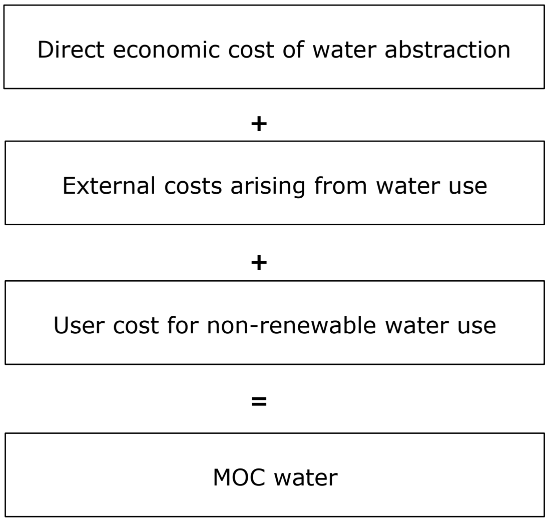

Figure 2.4 *The Marginal Opportunity Cost (MOC) for water depletion impacts*
Source: Turner et al. (2004).

The first component includes an assessment of direct economic costs of water abstraction such as the costs for labour, equipment and materials (see Turner et al., 2004). The second part includes the external costs that arise from water use. In this step the focus is on the net value of any losses and gains in welfare that water use imposes on individuals other than those engaged in the activity. This step thus requires an assessment of social, environmental and economic effects due to water abstraction and their valuation. The third step is relevant for non-renewable water sources (e.g. fossil aquifers) (e.g. Bierkens et al. 2019). If water from non-renewable sources is used, the value of the reduction of the source's water for future use is based on the size of the resource stock in relation to the rate of exploitation, the strength of future demand relative to present demand, the availability and cost of future substitutes (e.g. desalinated water) and the discount rate. This is a scarcity premium or 'user cost'.

The final marginal cost is then the sum of these three components. Information on this price is a useful principle as it puts attention on the externalities associated with water use, as well as guiding policy makers in setting water prices. The MOC focuses on the water system, the link with the food system is lacking.

2.3.3 Framework for interdisciplinary analysis of water resources

The FAO (Turner et al. 2004) developed an interdisciplinary analytical water framework that examines the value of water resources based on the linkage between water resource structures and processes and the goods and services that they provide at the necessary temporal and spatial scale (see Figure 2.5). An overview of this schedule is presented below.

The framework shows a chain of activities and steps to define the value of water for different users from human activities. The first step is to assess the environmental pressures caused by human activities. This may for example include the extraction of water for industries and discharge of wastewater in waterways. Depending on the scope or particular research question, pressures can be assessed on various scales from local (e.g. effect of industrial development on water extraction) to global level (e.g. effect of globalisation on greenhouse gas concentrations in air). The next step involves an assessment of the effects of these pressures on both water quality and quantity. This step thus involves an analysis how environmental changes or pressures affect the water system (alike stage 1 in the framework for trade-offs in groundwater uses (Section 2.4.1).

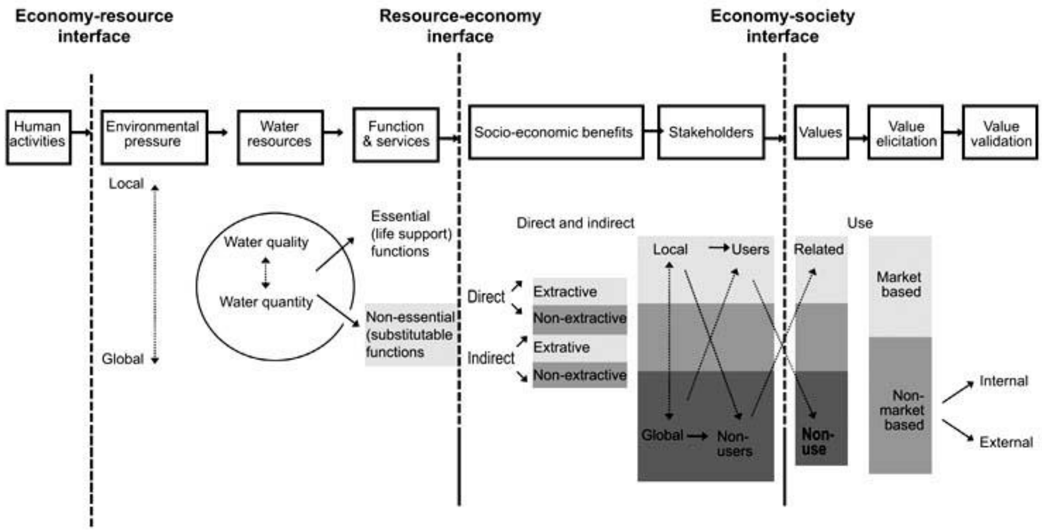

__Figure 2.5__ The interdisciplinary analytical water framework
Source: Turner et al. (2004).

From a valuation perspective it is required to identify the functions and services water provides and how this is influenced by changes in water quality and/or quantity. The functions and services may be different between scales and location. For example, water in cities may provide other (non)essential services compared to international river basins (such as shipping).

The water functions and services (or changes in functions and services) lead to several direct and indirect socio-economic benefits; this is the main reason for human activity. These benefits should be identified between different stakeholders as they may value benefits from the same service/functions differently (e.g. public sector versus private sector). To quantify the different values to functions/services, several economic approaches such as the Total Economic Value (TEV) method and Cost-Benefit analyses can be applied to derive market and non-market based values. The last step is to validate the derived values with actual prices for functions/services from human activities that affect the water system. This will for example reveal to what extent externalities are included in the price. Although parts of the food system will be covered by this framework, the food system is not explicitly linked to this valuation framework. Therefore parts of the food system might be overlooked in the analysis.

2.3.4 Synthesis

All three frameworks are developed as tools to quantify benefits and costs to enable trade-offs in water uses, where the value of the water used by different water users (e.g. different sectors) within a water basin is analysed and compared. However, water valuation is related to hydrological issues, while the relation with the food value chains or the food system as a whole (if relevant) is not yet incorporated explicitly. For example, effects of drivers of the food system such as consumer choices or population dynamics on the value of water is not yet explicitly incorporated in the above-mentioned frameworks, this also applies for the food security outcomes (see Section 2.5). A need exists to develop such a framework to capture the strong link between water, agriculture, food and food security. Before this link is presented, the next section first describes the concept of valuing food security.

2.4 Valuation of food security

Three components of food security are distinguished: food availability, food utilisation and food access, see Figure 2.2 (FAO 2015c). These components all have different drivers, scales and levels which complicate the analysis and quantification of food security. In contrast to the value of water, literature on the value of food security is sparse. Assessing the economic value of food and of food security remains challenging (Cafiero 2013). This value of food security is relevant for food policy to the extent that reducing food insecurity for all individuals is seen as an important policy. Achieving this goal can be done in several ways (linked to its components): by increasing world food supply, by improving access to food, and by increasing consumer food purchasing power goal (FAO, 2015c). The consumer value of food relates to its nutritional and health attributes that remain difficult to measure (Barrett 2010). These complexities have made it difficult for economists and policy analysts to assess food security issues and to design and evaluate programmes intended to reduce food insecurity. Some parts of this puzzle have been studied extensively: e.g. the effects of prices and consumer income on food consumption and the many factors affecting the supply of food (Chavas, 2017). The value of specific characteristics of food have been analysed in more detail, by comparing the willingness to pay of consumers of products with different characteristics: e.g. organic versus conventional (McFadden and Huffman 2017; Bazzani et al. 2017), or conventional and GM food (Valente and Chaves 2018). Chavas (2017) performed an economic evaluation of food and the cost of food insecurity, building on behavioural regularities of consumer behaviour. The analysis evaluates empirically the cost of food insecurity, which can be large in situations of exposure to significant downside risk.

Hence, frameworks to value food security do not exist yet. Most commonly the value of food taken into account in water valuation studies is the value of food produce at farm gate.

2.5 Food and Water Valuation Framework

To develop a framework that links water valuation to the food system approach, existing literature on water valuation frameworks combined with the food system were assessed. Jia et al. (2019) did an extensive literature review on water stewardship in the supply chain. They emphasise the value of water for the supply chain, with a focus on corporate water stewardship. This is related to the water footprint concept in the supply chain (Hoekstra 2017). Jia et al. (2019) and Aivazidou et al. (2016) acknowledge that although water efficiency in volumetric terms remains an important metric, there are broader perspectives to consider concerning where water is extracted and the impacts its use has at a local level, both environmentally and on alternative water users. Both papers analysed water use in the supply chain to minimise resource use, but both did not apply the concept of water valuation per se.

To better link water valuation with food security, the value of water should be assessed and applied in a food system approach. In the Food-Water Valuation Framework (FWVF), the aforementioned work on water valuation is combined with the Food System Approach. As the FSA is a generic approach for all food systems and regions, water valuation is also treated as a basic concept. Given the budget, the FWVF will be generic and focus on the value added of incorporating water valuation and FSA in the analysis.

The objective of this project is to support systemic change by valuing water in the food system. Hence the focus of the impact of valuing water is not the water basin (as in most valuing water studies), but the food system and its exposure to the environmental system. Over the last decades the focus of food security shifted from producing enough staples to the household’s access to healthy diets, whether consumers consume, in addition to consuming a sufficient amount of calories consume sufficient nutrients to become and remain a healthy person. The EAT-Lancet report, published early 2019, emphasised the importance of diverse diets on health and connects these healthy diets with sustainable food systems (Willett et al. 2019). The basis for the Food-Water Valuation Framework (FWVF see Figure 2.6) are the strengths of the aforementioned water valuing frameworks and food system approach.

Taking the broader perspective of the food system, the role of other aspects of the water system also becomes more relevant (tap water supply, infrastructure, sanitation and the sewage system). Water is a factor input for many activities of the food system, such as agriculture, food processing and consumption (van Berkum et al. 2018).

All described frameworks in Section 2.4 start with the identification of human interventions and/or activities on the water system from a water quantity and quality perspective. Moreover, all three frameworks in Section 2.4 explicitly take into account that changes in the water system affect the value of water services (ecosystem services, human needs). These may have positively or a negatively impact on the welfare of particular groups in society. The FAO interdisciplinary analysis of water resources framework (Section 2.3.3) is specifically focused on the benefits arising from changes in the water system, the other two examples also consider the trade-offs associated with certain changes in the water system. Another main difference between the frameworks is that the FAO framework specifically acknowledges different values to the same services (benefits) by various stakeholders. However, all three examples include some form of economic valuation of services to quantify the value of water for a specific human activity. Based on this overview and the Food System Approach, the agricultural water valuing framework as presented in Figure 2.6 is proposed.

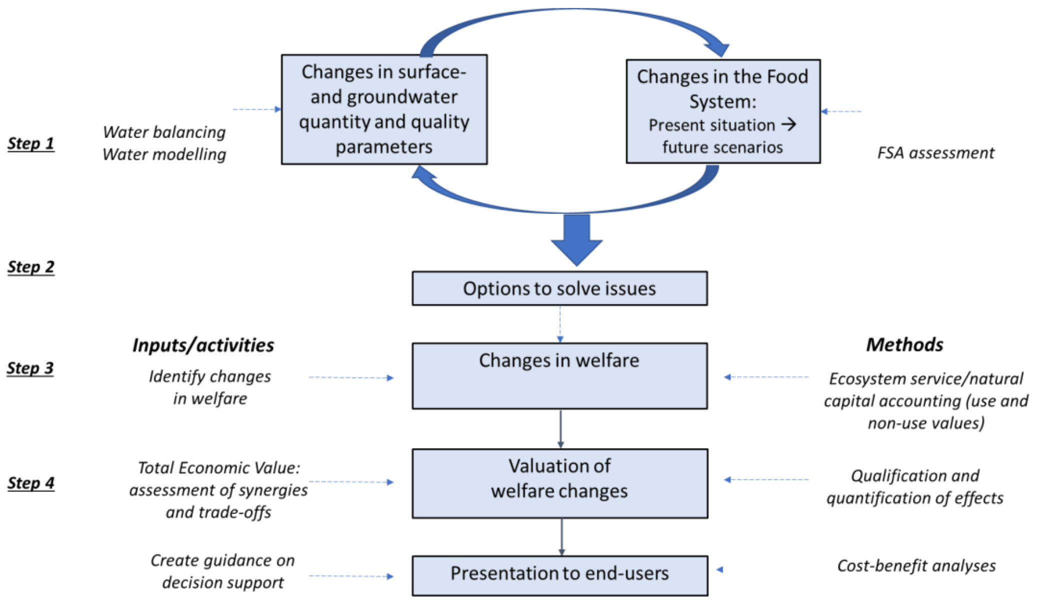

Figure 2.6 *Food-Water valuing framework (FWVF)*

In step 1, the Food-Water valuation framework (FWVF) starts with an assessment how (foreseen) changes in the food system' socio-economic drivers (e.g. changing food consumption behaviour) or in environmental drivers (e.g. climate change) affect the water system (see Figure 2.6). Based on local condition, effects of changes in the water system (e.g. salinisation of water bodies) on the food system may also be a starting point for this assessment. In either case the relationship between the food system and water system is key in this framework. This automatically implies that the framework is specifically useful for situations where water is a crucial and/or a scarce resource and food security is a policy goal. This can be the case on either local, regional or national scale. An example could be shortages of irrigation water to meet local food demand under a growing population or deterioration of water quality by industrial pollution that hampers agricultural production and tap water.

The second step is to identify possible options to address the aforementioned problems (in the water and food system). These options could be developed from a water perspective (e.g. alternative water use, non-conventional water use options) or from a food system approach perspective (e.g. influence consumer behaviour, adjusting the value chain).

The third step is to identify the (welfare) effects of each option. It must be made clear whether these effects are positive (benefits) or negative (costs). These welfare effects can be located at various levels. These effects on society, economy and the environment need to be assessed.

The final fourth step is to value (monetise) the benefits and costs through economic modelling such as TEV and MOC. Different options can be evaluated based upon the value of water to facilitate trade-off analysis based on the comparison of costs and benefits. It also shows which options maximise the value of water. However, benefits and costs are perceived differently by various user groups which also need to be taken into consideration. Therefore, a Multi-Criteria-Analysis with various stakeholders can be performed on top of a cost-benefit analysis to score/rank the various options for different user groups. The outcome of the economic and stakeholder analyses can then be presented to end-users to inform them on best options to be taken from a water perspective as well as raising awareness from a food system perspective (in which certain social principles such as safe drinking water for the poor are also taken into account).

Hence, the strength of the FWVF is that it connects water valuation frameworks with the Food System Approach. This connection is most important in step 1 and step 2. The FWVF does not prescribe actual methods to perform these steps, because they depend on the scale and scope of the policy issue, the data availability and the budget available for the analysis. Given the wealth of available methods it does not fit the scope of this project to present a catalogue of all available methods for each step. In this chapter references are given for more details on the various methodologies for each step.

The FWVF has obvious linkages with the OECD Triple Challenge. First, the connection between the food system and water in the FWVF is similar to the linkage between 'food security & nutrition' and 'resource use' as applied in the OECD Triple Challenge. Second, the FWVF is aimed at identifying options to maximise the value of water considering trade-offs on society (including economy and the environment). This is in line with the OECD Triple Challenge which also has a main focus on identification of synergies and trade-offs between resource use, food security and livelihoods. As such, the FWVF could well be used to address specific case studies that OECD is working on within the scope of addressing the Triple Challenge. Hence, the Triple Challenge has not been developed into an integral approach. The concept comes closer to the FWVF than VWI, but has currently a more generic scope missing the system dynamics from the FSA and indicators for valuation.

The FWVF also has multiple linkages with Valuing Water Initiative. The steps which cover the VWI principles are in line with the Food Water Valuation Framework:
- VWI Step 1: Define the system
- VWI Step 2: Determine the problem
- VWI Step 3: Evaluate what needs to be achieved

First, the protection of resources and maximising benefits from water use is in line with the assessment of the Food System Approach and water in the FWVF as the options all aim at sustainable water use and maximising the value of water for all stakeholders. Second, the FWVF acknowledges that synergies and trade-offs associated with options differ between users which is in line with the first principle of the Valuing Water Initiative. Third, the FWVF includes a presentation of the water valuation issues to end-users. This is required to raise awareness among stakeholders to use water resources sustainably and as such is in-line with the fourth principle of the Valuing Water Initiative. VWI solely focuses on water and its stakeholders, it misses the food dimension and food security policy goals.

2.6 Application of the Food Water Valuation Framework

The Food Water valuation Framework is applied, to analyse 'lessons learnt' in the worldwide application of valuing water in the food chain by a case study approach based upon literature. The framework is validated in two ex-post cases, where the value of water was used to decide upon water allocation within the food system. The framework was subsequently used for policy advice in two ex-ante cases 'country' cases, where will be demonstrated that applying the value of water explicitly in policy making, can lead to different optimal policies. The cases differ with respect to spatial scale (local, regional, national and international) and with respect to the decision maker (companies at the lower spatial levels and national governments at the higher level). The objectives of the valuing water analysis differ between companies (e.g. making a profit) and nations (e.g. improving the welfare of its inhabitants).

The four cases are presented in sections 3 to 6. The description of every case follows the methodology of the FWVF and presents relevant trade-offs. Given the budget, desk research was applied to analyse the cases based upon publicly available literature; no additional data collection and valuation exercises have been done. Hence, data for the trade-off analysis was not sufficiently available for a quantitative analysis. The ex post (Section 3 and 4) cases were assessed using publicly available data on valuation of water. For the ex ante cases (Section 5 and 6) a qualitative analysis was done, which can be elaborated upon in a next phase. This approach hampers the thoroughness of the analysis and the precise application of the FWVF in the case studies. But it will demonstrate that applying the value of water within the food system is useful to generate combined food and water security outcomes efficiently.

In the ex post cases it is checked which of the VWI principles (see Section 2.5.1) were applied in these cases. In the ex ante cases recommendations are given for the next steps based upon the valuing water principles. In all cases the options are scored qualitatively on goals, which are focal points of the OECD Triple Challenge.

3 Case study: Coca-Cola: valuing water at corporate level

3.1 Introduction

Coca-Cola, one of the largest companies in the world, owns four of the top five soft drink brands, and it makes or licenses more than 3,500 beverages tied to over 500 brands, providing 1.8 billion servings per day in over 200 nations (Fogel et al. 2012). Coca-Cola is a private company that operates worldwide; making a profit is a precondition for a (economically) sustainable company. The SDGs are not incorporated directly into Coca-Cola's corporate goals. However, some of them are related to SDGs. The focus is on actions already executed by Coca-Cola in the food system and water domain. We review these measures (an ex post analysis) and analyse the role valuing water played in the company's decision- making process.

3.2 Food and water system challenges

For the Coca-Cola Company water is needed for the cultivation of agricultural ingredients, water is used in the production process, and the beverage itself contains water. To better understand and manage water stress and risk, Coca-Cola conducted a global plant-level, water-risk assessment to define a global water strategy in 2015. This was a refresh of a risk assessment first conducted in 2004. The process involves a detailed, plant-level survey for each facility, extensive geospatial monitoring of various factors affecting water and a risk quantification model.

As described above in the introduction, Coca-Cola has formulated its own sustainability goals

- *Giving back*: Percentage of the company's annual operating income invested back into local communities (together with the jobs they supply, it can be seen as social and economic outcomes in FSA context, see Figure 2.4;
- *Water*: Percentage of water used in finished beverages returned to nature and communities; environmental outcomes in FSA context, see Figure 2.4;
- *Agriculture*: Percentage of ingredients sustainably sourced;
- *Food security* is not addressed directly, but the company's objective is to substitute sugar content to reduce obesity.

Coca-Cola's own system approach is depicted in Figure 3.1.

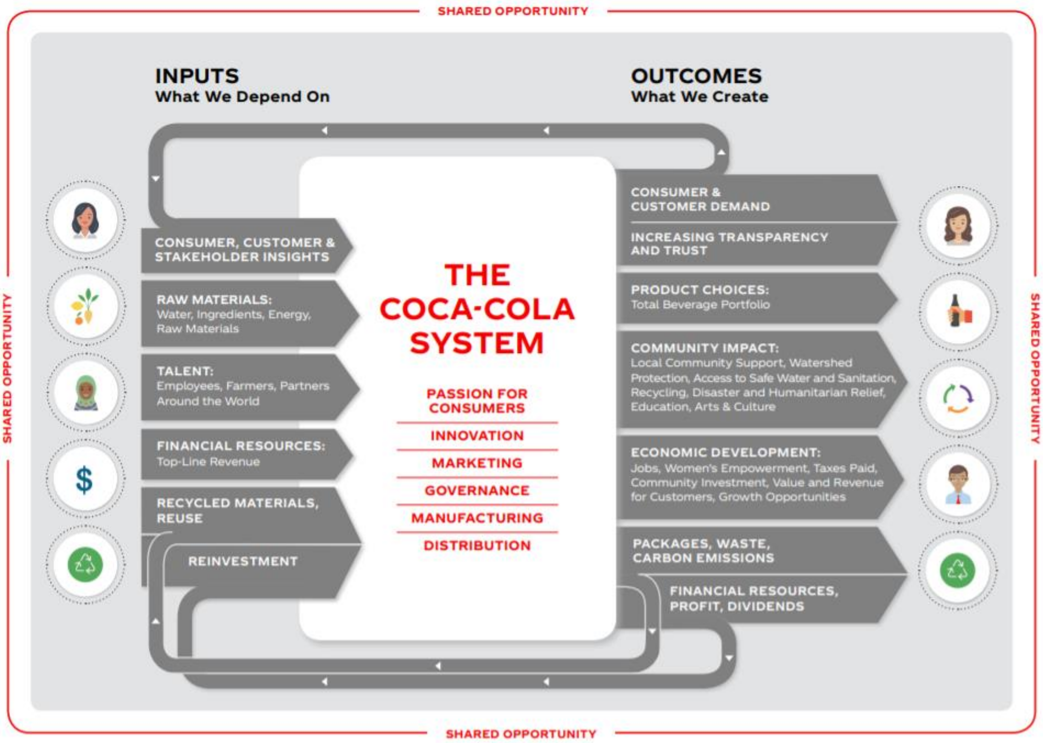

Figure 3.1 *The Coca-Cola system approach*
Source: Coca-Cola.

Sustainability of its water use was evaluated at community/watershed level including quantity, quality and the effectiveness of policy, as well as the social considerations of water and sanitation access, community engagement, government interactions and media. The assessment covers 99% of Coca- Cola's manufacturing system (Rudebeck 2018). Figure 3.2 presents the elements of the production process, the food chain, that have been taken into account.

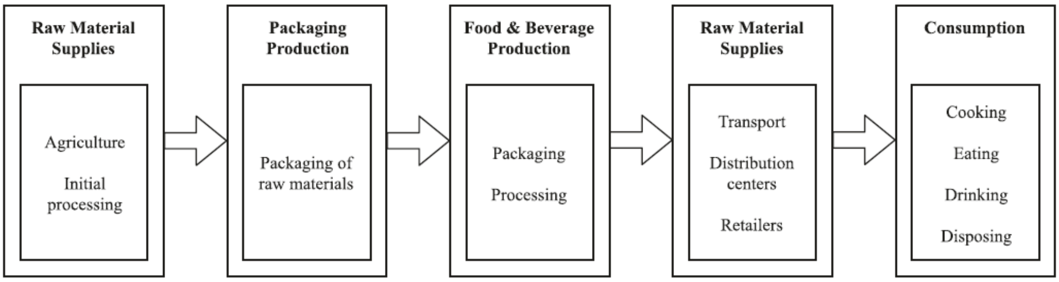

Figure 3.2 *Elements of the production process taken into account in Coca-Cola's sustainability analysis*
Source: Rudebeck (2018).

3.3 Options to increase the sustainability of water use

Coca-Cola has identified the following options to increase the sustainability of its water use;

1. Reduce water use in production and bottling process (less water use at plant site). The goal is to reduce water use by improving water efficiency (compared with 2004 levels). In 2004, 2.7 litres of water were used to make 1 litre of product. Today, Coca-Cola's water efficiency has improved by 31%.
2. Reduce water use of adjacent water users (less water use in the neighbourhood of the plant site), to reduce the business risk of insufficient water availability for the plant. Coca-Cola has a vested interest in local water resources, because of its embeddedness in local contexts using local resources. This

dependence means that when local water resources become scarce, it directly affects the business. Its water engagement is accordingly often a direct response to mitigating a risk (not enough water available to run the plant in the long run). Allocating production facilities in water scarce areas also carries a regulatory risk, particularly if there is competition between water users, since the companies risk having their water user rights withdrawn (WWF 2014).

3. Recharge local water system; treat wastewater and reuse it or make it available for local water system (more water available in the neighbourhood of the plant site). Coca-Cola has the ambition to replenish 100% of water used. They expand support of healthy watersheds and sustainable community water programmes to balance the water used in finished beverages by 2020. Coca-Cola will return treated water from its manufacturing processes back to the environment at a level that supports aquatic life and replenish the water used in its finished beverage products through continuing its community water projects with partners in more than 100 countries. Coca-Cola developed its own Source Water Protection Standard.
4. Reduce water use of suppliers (e.g. sugar producers) (less water use at regional/national scale). For food and beverage companies, the most water intensive activity is the production of agricultural inputs. For example, Coca-Cola estimates that 99% of the water it uses goes into the production of agricultural raw materials and packaging, while only 1% of the water is bottled in the beverage itself (Elmore 2015; Coca-Cola and TNC 2010). If the value of water increases, costs of production rise. Coca-Cola has defined its Sustainable Agricultural Guiding Principles (SAGP). The SAGP has three groups of guidelines (human and workplace right, environment, farm management systems). One of the elements of the group environment is water management:

   > ‘ensure long-term sustainability of water resources in balance with community and ecosystem needs by maximizing water use efficiency and minimizing water quality impacts from wastewater discharges and erosion and nutrient/agrochemical runoff’

   One of the reasons for developing SAGP is to mitigate business risk by addressing challenges to the availability, quality and safety of the agricultural ingredients and to balance the costs of sustainability by leveraging relationships. Coca-Cola Europe has proposed a methodology for water footprint sustainability assessments that considers impacts as well as water quantity.
5. Select water abundant regions to build a new bottling plant. No factories in water scarce areas. As production facilities have a long lifetime, an assessment whether water is available in future is necessary. Coca-Cola provided WRI (World Resources Institute) with data on water for its freshwater sustainability analyses (Aqueduct). Coca-Cola prefers to bottle beverages locally to reduce business risk, and reduce (transportation) costs. One of Coca-Cola’s new priorities is achieving 100% regenerative water use in bottling operations in water-stressed areas by reducing, reusing, recycling and locally replenishing the water they use.

The latter two options are based upon Coca-Cola’s food system and would not be taken into account if the analysis was tied to a water basin. These options and the way Coca-Cola have implemented them are evaluated in the next sections. Some of them are linked to the four water goals (Replenish, Reduce, Recycle, Risk) set by the company which are measurable and time bound to monitor progress (Fogel et al. 2012).

3.4 Value of water and effects on welfare

Being a beverage company, the value of water is important for Coca-Cola from different viewpoints.

1. Efficiency of the production process. Water is a direct input in the production process. The value of water in the long run is also important to assess the profitability of the production plants. The higher the value of water (in case of water scarcity), the more options are economically viable to reduce water use in its own production process. To improve their water efficiency, Coca-Cola has teamed with a number of organisations around the world. Notably, the company has worked with The Nature Conservancy (TNC) since 2008 to jointly build solutions to some of the world’s most pressing water issues (Fogel et al. 2012).

2. If water is used less efficiently outside the plant, it might be more efficient to support adjacent water users in reducing their water use. Then more water (a common pool resource) is available for the bottling plant.
3. The value of water for suppliers is important, because Coca-Cola depends on reliable sourcing of its ingredients. The value of water for all other local stakeholders in the region is important, if they do not take this value into account they end up in a struggle for water.
4. The value of Coca-Cola (a producer of low-value consumer goods) lies not in its products, but in its brand; the company is consequently highly exposed to reputational risk. This reputational risk, which denotes the potential loss of customers and brand value as a result of real, or perceived, negative impacts on communities and ecosystems as a consequence of a company's water use (Hepworth, 2012). Reputational risk is intimately tied to a company's 'social licence' to operate. The most prominent example of the links between reputational water risk and business continuity is the challenge that Coca-Cola faced in Kerala, India in 2003. Among other issues, serious concerns were voiced by the local community that the Coca-Cola bottling plant was over-extracting groundwater, and in effect depleting the local aquifer (Hills and Welford 2005; Coca-Cola 2004). After years of protests, the plant was closed (Chilkoti 2014).

3.5 Link with Triple Challenge and VWI

Coca-Cola understands water has a value for the company as well as for other stakeholders in water scarce regions. Instead of valuing water itself in the region of each production site, they have developed company guidelines and goals that increase water efficiency and the value of water. Progress on these goals is monitored internally and by benchmarking (e.g. BIER, Beverage Industry Environmental Roundtable). Based on their assessments they value water (at least implicitly) and they act on the values of water (e.g. increase the water use efficiency, by decreasing their own water use and the water use of the agricultural suppliers) to secure supply of agricultural products. The value of water for other stakeholders is important for Coca-Cola, because it affects the reputational risk.

Suitability of the FWVF. The four steps distinguished in the FWVF are reflected in Coca-Cola's approach. The company listed it challenges (Section 3.2; step 1). Coca-Cola's policy options fit the FWVF because they are anchored in their supply chain (step 2). Although we do not have insight in the exact method the beverage company used to value the effects of each option (step 3 and 4), we are confident they used their value of water and the value of water for the stakeholders (amongst others water users in the water basin and consumers of their beverages) to select their best option. Coca-Cola's non-water objectives such as 'contribution to livelihood, by offering jobs and income' fit in the socio-economic outcomes. Environmental outcomes are lined to water efficiency and wastewater treatment.

Link to OECD Triple Challenge
In Table 3.1 Coca-Cola's policy options are scores against the three dimensions of_OECD Triple Challenge, also the trade-offs for Coca-Cola are presented.

Table 3.1 *Trade-off table for Coca-Cola's option to reduce water use scored on OECD Triple Challenge dimensions*

Policy option	Food security and nutrition	Resource use and climate change	Livelihoods and rural development	Trade-offs
1. Reduce water in bottling process. Optimise own process	+	+	+	Costs to increase water efficiency of Coca-Cola's production process
2. Reduce water use of adjacent water users	0	+	+	Costs to increase water efficiency of adjacent water users
3. Recharge local water system	+	+/-	+	Water treatment costs additional to standard wastewater discharge
4. Reduce water use of suppliers	0	+	+	Water scarcity at the bottling plant does not have to be effected
5. Select water abundant regions	+	+/-	0	Less livelihood in water scarce regions. More transportation of bottles. More water available in water scarce regions

Legend: 0 – no effect, - negative effect, + positive effect, +/- effect can be either positive or negative.

Reduction of (Coca-Cola's) water use in water scarce areas (options 1,3 and 5) will increase the potential to grow food crops, and generate income from agriculture (Table 3.1). In all options water is used more efficiently. Some options might lead to higher energy input, these are labelled +/-. Livelihood and rural development are scored in Table 3.1 for the water scarce region.

Link with valuing water principles:

- **Principle 1**. *Recognise and embrace water's multiple values*. In decisions affecting water Coca-Cola takes care of their reputation and has started alliances with NGOs to secure their image as a responsible company. Coca-Cola partnered with nature conservation NGOs (e.g. WWF, TNC) and with NGOs with water focus (Water Stewardship, Virtual Water Network) to gain support for their work on increasing water use efficiency.
- **Principle 2.** *Reconcile values and build trust*. Coca-Cola has started to assess water resource availability for their bottling sites in risk areas, and have expanded their water assessments (water footprint analyses) to include other parts of the supply chain later (e.g. sourcing of sugar). They used these assessments to formulate their company policy with respect to water.
- **Principle 3.** *Protect the sources.* Focus on protecting the environment by increasing the water use efficiency. Coca-Cola's standards for wastewater treatment were set through a multi-stage and stakeholder engagement. Process wastewater regulations were reviewed from around the world to learn how governments are addressing those same parameters. All information was combined to arrive at the maximum allowable concentrations for each parameter. Coca-Cola wastewater treatment standards call for treatment of all water discharged at the agreed levels.
- **Principle 4.** *Educate to empower* see the partnerships with NGOs (see under principle 1) and through various projects (e.g. Coca-Cola 2019, 2020).
- **Principle 5.** *Invest and innovate.* Partnering with NGOs (see under principle 1).

4 Case study: Fresh water pipeline for high-value crop farmers

4.1 Introduction

The Southwestern Delta of the Netherlands is a region with a limited natural fresh water supply. Although most conditions for agriculture production are favourable in the area, the agricultural demand for fresh water is higher than the supply. For the province of Zeeland, agriculture is important for the area in terms of value added and employment, and it is one of the policy objectives of the province to maintain the employment and agricultural sector in the province. In this respect, the fruit growing farmers in Zuid-Beveland (see Figure 4.1) are a relevant group which have a demand for good quality fresh water demand. These farmers in Zuid-Beveland have been relying on fresh water supply from fresh water resources outside the Southwestern Delta since the 1990s with a fresh water pipeline from the Biesbosch (see Figure A1 in the appendix). In Section 4.2, we review the role of water valuation in the process of why this solution has been chosen for the fruit farmers in Zuid-Beveland. In addition, Section 4.3 discusses the alternatives to expand the fresh water pipeline to other areas in the Southwestern Delta (Walcheren in particular, see Figure 4.1), so that agriculture in these areas could benefit from the fresh water supply as well (higher productivity and more employment).

Figure 4.1 *Map of Zuid-Beveland in the Southwestern Delta*

4.2 Food and water system challenges Zuid-Beveland

Water system analysis

In Zuid-Beveland the water company Evides exploits a fresh water pipeline to supply fresh water to high-value crop farmers in the area (mainly pear and apple growing farmers). The purpose of the pipeline is to provide high-quality fresh water for high-value crop growers to avoid damage of night frost in spring and to avoid damages of water shortages in growing seasons. Figure 4.2 shows the map of the pipeline infrastructure. Below, we will discuss the value of the pipeline in its current situation.

Since 1992, the fresh water pipeline has been constructed to supply high quality fresh water to high-value crop producers in Zuid-Beveland. Initially, the fresh water pipeline’s high quality water was abstracted from the Bath-Spui canal in the eastern part of Zuid-Beveland (van Hoorn and Visser 2012). However, the water quality in the Bath-Spui canal decreased due to the presence of blue algae which led farmers to abort their irrigation system equipment. Therefore, the water management authorities, the water company Evides and the farmers searched for alternatives. In fact, there were two alternatives. The first option was that water could be abstracted from other fresh water resources (lakes or canals) in the Southwestern Delta. The second option was that a connection was made to the existing water pipeline for industrial water from the Biesbosch (North-Brabant) to the chemical industry in Zeeuws-Vlaanderen.

Alternative sources of fresh water (Option 1) have been researched, but these were far more expensive. In 1998, the supply of fresh water for high-value crop farmers in Zuid-Beveland was connected to the pipeline for industrial water (van Hoorn and Visser 2012). Although this was supposed to be a temporal solution, the fresh water pipeline for fruit farmers is nowadays still supplied with water from the industrial water pipeline.

Ten years after the connection was established, the option of using water from the Volkerak-Zoom lake was investigated but also this option was too expensive (van Hoorn and Visser 2012). The water from the Volkerak-Zoom lake is not suitable for usage by the high-value crop growing farmers. Since the Volkerak-Zoom lake had brackish water, for instance, the water had to be infiltrated into the soil in designated areas (about 15 ha) to remove impurities (van Hoorn and Visser 2012).

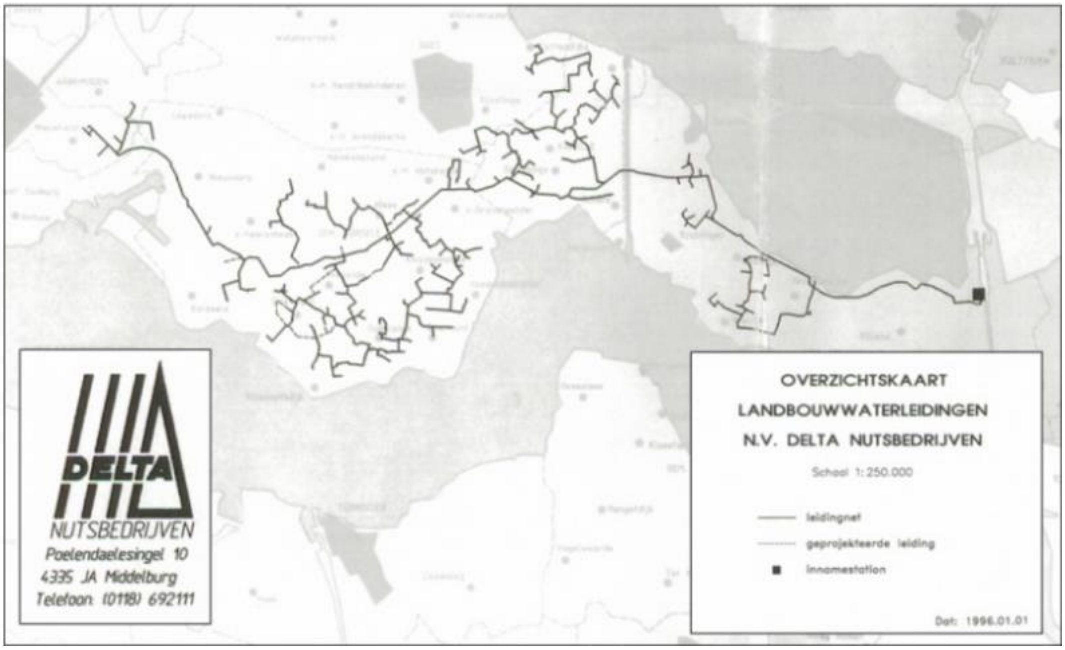

Figure 4.2 *Map of the fresh water pipeline in the Netherlands*
Source: Schipper et al. (2013).

These fruit producers in Zuid-Beveland use the high-quality fresh water of the pipeline for two purposes. First, they use the water to sprinkle their fruit trees to protect them and to avoid damage from night frost in spring. Night frost damage to permanent crops like pears and apples during the flowering stage may destroy the yields of the season. Second, the water is used to overcome water shortages due to limited rainfall during the growing season in summer. Water shortages might have two effects. With irrigation systems, fruit farmers can avoid the effects of drought spells and soil salinisation on crop yields. Hence, the presence of the pipeline has reduced the risk of night frost damage and damage of yields due to droughts. In the summer of

2018, however, the period of droughts was longer than expected and the water supply of the fresh water pipeline was insufficient to fulfil the peak demand for water (Lanting 2019).

Although peak demands for water can be high, the common agricultural demand for water is only a minor part of the available fresh water resources from the Biesbosch. The majority of the water resources are used for industrial purposes (chemical industry) and drinking water purposes (van Hoorn and Visser 2012). Before the fresh water pipeline of Zuid-Beveland was connected, there was already a fixed price per cubic meters. For the water supply of the farmers in Zuid-Beveland, alternative water resources were explored, but the cubic metre price was higher for farmers in all alternatives (ZLTO 2011). Many high-value crop farmers in Zuid-Beveland have their own water storage facilities to store water supplied and to use it in times of water shortages.

Link to food system approach
From the perspective of a food system approach (van Berkum, Dengerink, and Ruben 2018), fruit growing is mainly an agricultural production activity. A quarter of the fruit grown in the Netherlands originates from the province of Zeeland (van der Vleuten and Giele 2019). Other major fruit growing areas are the Betuwe and Zuid-Limburg. In the province of Zeeland, there is about 5,000 ha of fruit. The fruit growing area of Zuid-Beveland amounts to 3,420 ha, and the main fruit crops are pears and apples. In Zuid-Beveland, a third of the Dutch pear production is grown, and almost 20% of the Dutch apple production (van der Vleuten and Giele 2019). The total production value of fruit produced in the province of Zeeland was almost 100 million euros. Fruit is bought by fruit traders and distributed in the Netherlands and exported abroad. From a consumer perspective, fruit consumption is a valuable source of micro-nutrients such as vitamins (and fibres). There is no specific information on fruit consumption in Zeeland or Zuid-Beveland, but the fruit consumption per person per day is below the recommended amounts for a healthy diets (Dijkshoorn-Dekker et al. 2019). For the fruit growers and the province of Zeeland, the key aspect in decision making has been the continuation of the fruit production and the corresponding employment in the province of Zeeland.

Valuation of water
The fresh water pipeline is exploited by the drinking water company Evides. Fruit farmers in Zuid-Beveland connected to the pipeline only pay for the fresh water amount they used. In 2013, the high-value crop farmers paid approximately €0.60 per cubic metre (Stuyt et al. 2013). Farmers did not pay any fixed charge to the water supplying company. On-farm water storage facilities and irrigation equipment, however, were paid by the farmers themselves. For farmers with high-value crops like fruits (apples and pears mainly), the connection to the pipeline is beneficial.

4.3 Food and water system challenges of Walcheren

The use of the fresh water pipeline for high-value agriculture in Zuid-Beveland has been successful for years, see the previous section. Policy makers (province of Zeeland and the regional water authorities) were interested to boost economic developments of other areas of Zeeland as well. As a result, the option to extend the current fresh water pipeline to Walcheren was investigated. However, it was not only an extension of the pipeline but also an expansion of the capacity of the existing pipeline, because the capacity of the pipeline in Zuid-Beveland was hardly sufficient to fulfil demand for agricultural water in Zuid-Beveland.

Water system analysis
So far, there is no fresh water supply for farmers in Walcheren. For fresh water, the farmers mainly rely on precipitation and groundwater. Additional fresh water supply could open up opportunities to start growinghigh-value crops in Walcheren, so that the agricultural productivity of Walcheren can be improved as well as the economic prosperity and employment.

Link with food system approach
The link with the food system approach of the Walcheren expansion is similar to the one of the existing Zuid-Beveland connection. For the province of Zeeland, the key aspect in decision making of the expansion of the pipeline Walcheren would be the improvement of agricultural productivity in Walcheren from low-value crops

(cereals and pulses) to high-value crops (fruit like apples and pears) to improve income for farmers from Walcheren.

Valuation of water
The expansion of the pipeline to Walcheren has several additional consequences. Farmers would change from annual arable crops to higher value crops and even permanent crops, like fruit trees. In addition, the farmers would have to invest in a detailed distribution network in Walcheren. Moreover, farmers must invest in irrigation equipment and they have to consider whether they would like to have water storage facilities on-farm or not.

The current pipeline in Zuid-Beveland will have to be replaced by a pipeline with a larger capacity (doubled), so that the water flow capacity of the pipeline can be increased to serve more (fruit) farmers (Schipper et al. 2014). The current pipeline capacity is 1 cubic metre per second, and with the expansion, the capacity should be increased to 2 cubic metres per second.

Table 4.1 *Annual costs and benefits (x €1,000) of the expansion of the fresh water pipeline to Walcheren with a land-use conversion from arable crops to fruit trees (pears and apples) over a 50-year period*

Description	**Annual costs**	**Annual benefits**
Construction and replacement	13,282	
Distribution network	626	
Transition to fruit trees	2,939	
Water supply	6	
Change of damages due to droughts, flooding and salinisation	257	
Benefits of agriculture		8,859
Total	17,111	8,859

Source: Schipper et al. (2014).

Based upon a cost-benefit analyses over a fifty-year period (see Table 4.1), the expansion of the pipeline to Walcheren is not profitable even if farmers in Walcheren would switch from low-value arable crops to high-value crops like fruit.

4.4 Link with Triple Challenge and VWI

Suitability of the FWVF
In step 1 the challenges are identified: to continue the fruit growing activities to secure economic activities and employment for Zuid-Beveland. If nothing is done, farmers might need to turn to low-value, water-extensive crops, because the demand for fresh water demand of high value crops cannot be met. This will negatively affect the livelihood of the Zuid-Beveland area.

The two options (step 2) were assessed for fresh water supply for Zuid-Beveland. Both options are compared to the scenario in which nothing is done (BaU), see Table 4.2.

The effect of the options (step 3) is that in the case of using water from the Volkerak-Zoom lake, the production and productivity of agriculture could be largely maintained, although water from the Volkerak-Zoom lake might be more brackish than from the Bath-Spui canal (reducing productivity) and agricultural land is required for treatment of the water (lowering production). However, there are no problems expected with the irrigation systems due to the poor water quality. As a result, the impact on food security and nutrition is uncertain and might be either higher or lower.

The valuation (step 4) revealed that the connection to the fresh water pipeline (Option 2) was cheaper, and it was more secure for maintaining the production and productivity of agriculture. There are no additional costs for water treatment, so the livelihood of Zuid-Beveland would improve.

For the Walcheren case, the opportunities to improve production from agriculture and as a result the livelihoods and rural developments are promising, but the costs of investments in the pipeline extension and expansion outweigh the benefits for society.

Link with OECD Triple Challenge
The link with the *OECD Triple Challenge is presented in Table 4.2.*

Table 4.2 *Impact of the options on food and nutrition security, resource use and climate change and livelihoods and rural development based on the OECD Triple Challenge dimensions*

Policy	Food security and nutrition	Resource use and climate change	Livelihoods and rural development	Trade-offs
Zuid-Beveland (Section 4.2)				
Option 1 Fresh water from alternative fresh water resources like the Volkerak-Zoom lake	+/-	0	-	Less livelihood in Zuid-Beveland due to higher costs for water treatment. Production or quality of production is uncertain and could go both ways
Option 2 Fresh water from industrial pipeline	+	0	+	Better livelihood in Zuid-Beveland and higher or more secure levels of production
Walcheren (Section 4.3)				
Option 3 Water pipeline for Walcheren	+	0	-	Costs of investment outweigh the increase production, which has a negative impact on livelihoods

Legend: 0 – no effect, - negative effect, + positive effect, +/- effect can be either positive or negative.

In summary, the use of the fresh water pipeline has been beneficial from a food and nutrition perspective and the improvement of livelihoods and rural development. The natural resource and climate change are hardly affected. In the case of the extension of the pipeline to Walcheren, there is a clear benefit from a food and nutrition security perspective, because agricultural productivity and production can be achieved, but the costs of construction would put a larger burden on the livelihoods and rural development than the benefits for the agricultural sector.

Link with valuing water principles:

- **Principle 1**. *Recognise and embrace water's multiple values*. As part of an existing fresh water pipeline for the chemical and drinking water industry, the supply of good-quality fresh water to fruit farmers in Zuid-Beveland is one of the (minor) water uses. The organisations involved are Evides, the drinking water company and operator of the pipeline, the chemical industry, the fruit farmers and regional water boards and the province of Zeeland. The province of Zeeland has a high value for water supply, because they prefer to continue the economic development of agriculture and employment. The fruit farmers have a high value for water during particular periods of the growing season. In addition to the price for water supplied through the fresh water pipeline, farmers also invest in expensive irrigation equipment and water storage facilities. These investments are only profitable with high-value crops with high productivity. The Regional Water authority can fulfil their obligation and responsibility to provide sufficient fresh water in their service area. Evides have a modest value for water, because the exploitation of the fresh water pipeline is not profitable for them. The chemical industry is trying to lower the value of water supply by researching alternative ways of water supply, such as water reuse.
- **Principle 2.** *Reconcile values and build trust*. The fruit farmers who benefit were charged for each cubic metre of water they used. The impact of the water abstraction of the Biesbosch is regularly monitored by Evides, the water company exploiting the fresh water pipeline. Except for the price per cubic metre, no transparent analysis has been published of the value of water due to the strategic character of the information.
- **Principle 3.** *Protect the sources.* Evides not only manages the fresh water pipeline but also the fresh water resources in the Biesbosch.

- **Principle 4.** *Educate to empower.* Evides, the operator of the fresh water pipeline provides all kinds of promotion materials on how they manage water for their clients (industrial water including water for farmers and drinking water) via their website.
- **Principle 5**. *Invest and innovate.* Evides manages the supply of sufficient fresh water for Zeeland. Fruit farmers connected to the pipeline invested in the connection from the pipeline itself. The regional water board is a major partner as the responsible authority of good quality surface water in the area, and the province is a major partner in this process as well, because they want to secure the agricultural activities and the related employment for the province.

5 Case Study: increase national self-sufficiency for wheat in Jordan

5.1 Introduction

Jordan is the second most water scarce country in the world with a renewable water availability of some 100 m^3 per capita per year (IWMI 2016). This value is well below the absolute Water Stress Indicator of 500 m^3/pcpy (Falkenmark et al. 1989). A fast population growth, strings of refugee crises, effects of climate change, and political conflicts on sharing water resources exacerbate the problem further. The water scarce situation of Jordan is clearly visible when water extraction and inputs of water are compared: the annual renewable internal fresh water resources are some 0.9 km^3/year while the extraction is estimated at 1.2 km^3/year (Salameh et al. 2014, and MWI 2011). Roughly 50% of the total water withdrawal is allocated to agriculture (but its share is declining over time), while the remainder is used by households and industries (Salameh 2014). Moreover, Jordan is also facing severe soil degradation due to wind erosion as well as increasing soil salinities caused by unsustainable irrigation practices. Over 90% of the country’s food supply is imported, particularly wheat (WB 2012, OEC 2017). Jordan’s development is sharply impeded by water shortages and agricultural production under current circumstances is thus experiencing significant challenges. Without a significant shift in policy, the country faces potential food and water insecurity (Ramırez, Ward, Al-Tabini, and Phillips 2011).

5.2 Food and water system challenges

5.2.1 Current agricultural situation

Jordan has two main agricultural regions: 1) the Jordan Valley in the Northwestern region which is irrigated by water from the King Abdullah Canal and 2) the highlands stretching from the North to the South (and covering Amman too), which depend on underground water for irrigation. In 2018 the total cultivated area amounted to approximately 10,000 sq. km (WorldBank, 2020). According to FAO AQUASTAT (2018), 83% was irrigated and the remainder rainfed.

Agriculture accounts for 3.7% of the GDP in 2015 (IWMI 2016). Some 15% of the (working) population derives its main income source from primary production, while this number rises to 25% if the whole chain is included. Jordan is far from self-sufficient and imports 90% of its cereals, 80% of its animal fodder, and 42% of its animal products. This percentage is high compared to the global average of 5% (OECD/FAO, 2018). The high dependence may be a risk to food security and could lead to potential conflicts.

The country has a comparative advantage in that its harvesting seasons in the Jordan valley coincide with profitable regional and international export windows. For fruits, for example, the self-sufficiency rate is 139% (OECD/FAO, 2018), which shows the export capacity for these agricultural products. Although regional conflicts have severely impacted these markets, it is expected that export of fruits and other cash crops can be enhanced.

5.2.2 Food system elements affecting the agricultural water system

Various socio-economic, population and environmental factors may influence the water system, both from a quantity and quality perspective. The major changes are presented below.

5.2.2.1 Socio-economic changes – policy priorities

The agricultural policy in Jordan aims to promote efficient and sustainable use of rural resources while increasing economic opportunities. The Government of Jordan also faces the absolute necessity of ensuring that the population has access to basic foodstuffs at stable prices that preserve the living standards of limited opportunity and the lowest income groups (Ibrahim and Mashhour 2012). As a result, policies are directed at increasing Jordan's food self-sufficiency through export of high-value agricultural products (fruit, vegetables) and import of lower value goods such as cereals (Ibrahim and Mashhour 2012). This requires a shift in agricultural water demand as water requirements of cash crops are generally higher compared to cereals. The exact change depends however on increase of cash crop production and cultivation methodologies and needs to be further assessed.

In brief, Jordan's water policy (Water strategy of 1998) has made a shift from supply management towards demand management. Currently, the policies have turned around again as demand management is not favoured due to the perception that water is a free good. Jordan is stimulating reuse of wastewater and seeking solutions to provide the Amman conglomeration of drinking water for the near future. Because of the over-abstraction of groundwater stocks, agricultural regulation policies are still in place. These focus on e.g. strengthening of agricultural extensions to promote water efficient technologies and systems and increasing waste-water usage for agriculture (Molle et al. 2008)

5.2.2.2 Population growth and dietary changes

Population growth is putting further pressure on the national water demand although the growth percentages are expected to significantly decrease from 4.5% between 2007-2017 to less than 2% between 2017-2027 (OECD/FAO, 2018). The World Bank population growth data (2020) indeed revealed a population growth of 1.8% in 2018 versus growth rates between 3 and 5% in the period 2012-2016. The population growth reduction in the last years may be caused by reduced annual inflow of Syrian refugees.

The food consumption in Jordan is around 3,150 kcalories per capita per day through consumption of cereals (45.5%), animal products (12.4%), sugars (12.9%), vegetable oils (16.6%) and vegetables (2.6%) (FAO 2011). The consumption pattern is expected to grow at 0.4% per year due to modest income gains (OECD/FAO, 2018). In addition, dietary patterns are expected to change as well. Consumption forecasts for the MENA region indicate increased cereal intake of 0.7% from 2015 to 2023 while sugar intake is expected to increase by 12.1% (FAO 2015b). From a water perspective, the intake of meat and dairy products is relevant and shows an expected increase of 7.2% and 6.7% between 2015 and 2023 (FAO 2015b). Based on the above it can be concluded that agricultural water demand from population growth and dietary changes is expected to increase.

5.2.2.3 Environmental changes – climate change

Prognoses of climate change effects look especially worrisome with significant changes in precipitation and much higher temperatures in Jordan's main productions areas. Over the last decades, temperatures have risen over 0.5 degrees Celsius and precipitation reduced to over 10%, varying per region (OECD/FAO 2018). As a result, rainfed agricultural lands are under increasing pressure due to climate change. Due to climate change and population growth the share of irrigated areas is expected to decrease by 20% in the highlands, the rainfed areas by 11 to 18% and the forests by 30 to 50% by 2050 (Al-Bakri et al. 2013). To maintain agricultural production this will lead to increased water stress and demand for irrigation, reduced yields, salinisation of agricultural lands and reduction in crop intensity (OECD/FAO, 2018).

5.3 Options for enhanced agricultural water management from a water value perspective

Jordan's current policy is still focused on demand management and regional cooperation through appointments with neighbouring countries on water sharing being a key component in accessing international funding (Beyth 2007; Viviroli et al. 2011). However, demand management programmes in agriculture have largely proven to be ineffective. The main reasons were that 1) during the 'demand oriented transition phase' (Curtis et al. 2008) the local culture did not allow for 'treating water as an economic good' and that 2) compliance on restricting access to unsustainable withdrawal practices through wells from groundwater stocks were unsuccessful.

As the scope for new fresh water resources within the national boundaries has been exhausted, and water demands will go up due to population dynamics and climate change, several options could be considered to meet the national demand of food supplies. In this case study wheat is selected, as this agricultural commodity is a basic and important food supply. Moreover, wheat is the most important agricultural commodity in Jordan.

The following four options could (in part) meet the challenge to achieve wheat demand in the future:
1. Increase the agricultural exports of cash crops to partly compensate for the (agricultural) imports of basic food supplies such as wheat.
2. Extend the acreage of rain-fed wheat.
3. Set up a new agricultural water demand management programme.
4. Develop desalinisation plants. This option includes expansion of desalinisation technologies to create fresh irrigation water from saline/brackish water sources. It would provide additional water resources able to maintain – or even expand – the agricultural sector in Jordan, which would lead to increased exports and a better self-sufficiency.

A brief overview of the four alternative options are presented below:
Ad 1) As Jordan has few export commodities, the export of agricultural products has been a mainstay in the trade balance. Unfortunately, the regional crises in Syria and Iraq have severely undercut this position. A recovery and further increase of the export sector is a policy focus of the Jordanian Government and is also supported by the Netherlands. At present the country imports some 97% of its wheat requirements. According to OEC (2017), the trade balance for agricultural commodities is in negative territory at an amount of some USD 985m in 2017. Increasing the export market through foreign sales of cash crops (fruits and vegetables) reduces the agricultural trade balance deficit.

Ad 2) Most wheat is grown on the north-western plateau where on average some 500 mm of rainfall is available. The option would be to (partially) convert remaining natural areas on the plateau to agricultural land to cultivate wheat. This would (modestly) reduce the dependency on imports, while not drawing on the scarce water resources as the rainwater is currently evaporated by natural vegetation. OEC (2017) quotes a value of USD 347m for imported wheat, which again is contingent on local harvests (under rather erratic rainfall conditions). The high dependency on these imports (97% of the demand) pushes the Government to stimulate local production.

Ad 3) Several options are available to produce more crop with less water, such as high-tech protected agriculture (e.g. greenhouses). This programme would also include a payment system for agricultural water use which would stimulate the optimisation of water usage and thus increases the value of water. Finally, the limits for groundwater abstraction - where opportune - should be clearly defined by sustainability considerations. A modernisation of the agricultural sector is already underway with significant support from the Netherlands. The point here is that for significant improvements in terms of higher yields against a lower water consumption not only large investments will be required, but that also the knowledge level of the sector needs to be enhanced considerably to operate and maintain such new systems. For financial viability, the modernisation needs to be linked to the export sector (option 1).

Ad 4) The desalination option (Red Sea – Dead Sea axis) cannot be financed by a country running a trade deficit of JOD 674.9m and a government deficit of 5.3% of the GDP in 2011. Options could be to jointly finance the plan with other regional stakeholders or through foreign development aid such as from the World Bank, FMO and donor countries. A feasibility study is required to explore the potential of desalinisation of water for the agricultural sector in a very competitive market.

As option one is already executed in Jordan and it is very unlikely that usage of desalinated water for wheat cultivation will be feasible, these options are not further assessed in this case study. Option three is also not considered as the agricultural water demand programmes should be linked with option one. Thus, for the purpose of this study (i.e. to test the application of the FWVF framework), the second option is further explored and described more in detail.

5.4 Resulting changes in the water and food systems

The selected option (convert remaining natural areas on the plateau to agricultural land to cultivate wheat) has limited or no effects on the water system in Jordan and is expected to have some effects on the welfare conditions. This is further elaborated upon below.

5.4.1 Direct effects on the water system

Water quantity
Land-use conversions from natural areas to rain-fed wheat cultivation will take place in the North-West of the country where on average 500 mm of rain is available on an annual basis. The total annual evapotranspiration is unlikely to change very much as rains only occur during the winter half year and wheat (or barley) are winter crops. The risk may be that farmers would also prefer to cultivate summer crops which would require groundwater from ancient aquifers and thus putting pressure on limited groundwater sources. This should however be further assessed.

Water quality
In 2017, pesticide usage in Jordan was 1,289 tonnes or 4.9 kg of pesticide per hectare of cropland (WorldOmeters 2017). According to information from the Jordan Agricultural Information System (Alhawamdeh 2012), overuse of pesticides is common in Jordan, especially for tomatoes. However, the fertiliser usage showed a decrease over the period 2002-2016 from 1,590 to 112 kg per hectare of arable land (Knoema 2016). As the use of pesticides on wheat will be limited, while the groundwater table will be deep and no drainage on surface waters will occur, it can be predicted that their contamination by agro-chemicals will not be an issue of concern.

In summary, effects on the water system due to extended wheat cultivation are expected to be minimal. There is however a risk of unsustainable groundwater extraction in summer time, this extraction needs to be well enforced.

5.4.2 Effects changing water system on welfare

The selected option of expanded rainfed wheat cultivation brings various positive changes on the welfare in Jordan but also involves several trade-offs. A brief summary, based on relevant indicators for Jordan, is presented.

Marginally improved import-export balance
According to OEC (2017), the net agricultural trade balance was USD -985m for agricultural commodities in 2017. The agricultural export value is USD 535m (dominated by tomatoes, vegetables and fruits) while the agricultural import value is USD 1,520m (dominated by wheat, maize, rice, barley and coffee) in 2017.

Land-use conversions for wheat cultivation may marginally improve this deficit. For a further quantification an estimate needs to be made of the lands available and suitable for such conversions.

Increased self-sufficiency
This option will marginally increase national self-sufficiency for staple crops. With current grain imports at 97% of domestic demand and a limited area where rain-fed wheat can be grown, little significant increase of the self-sufficiency rate can be expected. However, the expected self-sufficiency rate of wheat should be further assessed also within the scope of other changes in the food system (population growth, dietary changes, etc.).

Water conflicts
Wheat will not be under irrigation and will generally not affect water resources during the winter time (growing season of wheat). Negative effects on (local) water resources may only be expected if lands with natural vegetation are converted into wheat fields and are subsequently irrigated for summer crops through ancient groundwater resources. In this case other water users may be affected. This may occur in the form

of higher pumping costs or the upcoming of brackish groundwater, which may result in higher energy costs or may render the water unsuitable for its intended consumption.

Increased risks for smallholder farmers
A vast majority of farmers in Jordan are smallholder farmers (<1 ha/farm) (OECD/FAO 2018). Smallholder farmers are generally risk averse as crop failure leads to dramatic personal financial situations. As such, smallholders prefer to diversify crop production in order to have agricultural yield security. The cultivation of a crop depending on erratic rainfall and a competitive farmgate price when compared to imports would not be attractive without subsidies. Moreover, a cash-strapped government will not be in a position to provide such subsidies on a large scale.

Ecological damage
Ecological damage of this option is to be expected if natural lands need to be converted into wheat fields. In case fields are not cultivated during summer, wind erosion may play havoc on soil fertility.

5.5 Description of costs and benefits

This section qualitatively describes the benefits and costs associated with converting natural lands in the north-western plateau of Jordan to agricultural lands for rain-fed wheat cultivation. Information to quantify these costs and benefits is not readily available. The option analysed has been compared with the situation where the agricultural area in the north-western plateau will not increase and the plateau maintains its function as a natural area (Business-As-Usual or BAU).

Effects of extended wheat cultivation in the north-western plateau has moderate benefits with respect to closing the import/trade balance gap and increasing self-sufficiency of basic food supplies. Although this option will be far from sufficient to close the agricultural trade balance gap, the small increase in becoming more self-sufficient with respect food security and nutrition is positively judged.

Although additional farm land may generate new employment opportunities, wheat is a relatively low-value crop compared to fruits and vegetables which may result into low income for farmers which puts their livelihoods under pressure. There may therefore be a need to compensate farmers, also within the scope to reduce incentives of illegal groundwater extraction in summer time (dry season) to generate additional income from these lands. Due to these counter-effective circumstances, the livelihood and rural development indicator is given a neutral score.

Increasing farmland from converted natural areas leads to increased risks of unsustainable groundwater extraction in summer time this extraction needs to be well enforced (see former remark). Moreover, increasing wheat acreage will reduce the existing nature and biodiversity which is therefore a main trade-off of this option. As a result, the effect of this option on resource use is judged as negative.

5.6 Link with Triple Challenge and VWI

The OECD Triple Challenge objectives are linked to the benefits and costs of the elaborated option to convert remaining natural areas on the plateau to agricultural land to cultivate wheat when compared to the BAU situation. The Triple Challenge objectives have a higher abstraction level than the indicators used in this case study (Section 5.4) and are related as follows:
1. Food security and nutrition – increased self-sufficiency, import/export balance.
2. Resource use and climate change – water quantity and quality, ecology.
3. Livelihoods and rural development – risk for smallholder farmers, water conflicts.

Table 5.1 presents the benefits and costs associated with increasing rainfed cultivated wheat plantations in Jordan using the OECD Triple Challenge objectives.

Table 5.1 *Impact of the options on food and nutrition security, resource use and climate change and livelihoods and rural development based on the OECD Triple Challenge dimensions*

Policy option	**Food security and nutrition**	**Resource use and climate change**	**Livelihoods and rural development**
Increased rainfed wheat cultivation	+	--	0

Link with valuing water principles:
As this case study describes an ex ante scenario (a potential option), this section describes how the VWI principles can be applied.

- **Principle 1**. *Recognise and embrace water's multiple values*. During the identification of benefits and costs, different stakeholders should be involved to value and rank the various indicators. These stakeholders should involve both public- and private parties which allows for identifying potential opinions on the value of water (e.g. stakeholders may perceive value of water for nature and biodiversity differently). During various stakeholder workshops differences in opinions can be discussed and solutions can be negotiated between users.
- **Principle 2.** *Reconcile values and build trust.* Some stakeholders may be in favour of this option while others prefer maintaining the natural areas in its current shape. Mutual understanding and the possibility to discuss different points of view between stakeholders helps in building trust between parties.
- **Principle 3.** *Protect the sources.* Increased wheat cultivation may lead to ecological damage and may put pressure on groundwater resources if this option is actually implemented. Ecological effects should be identified and considered in the final decision whether or not to expand wheat cultivation.
- **Principle 4.** *Educate to empower.* Following the process of stakeholder consultation raises awareness of both policy makers and private sector parties on both benefits and costs of implementing this option. In Jordan this may be in the form of capacity building activities on proper groundwater management and restoration/maintenance of natural areas.
- **Principle 5.** *Invest and innovate.* Both government and the private sector will need to invest if natural lands will be transformed to wheat cultivated areas. When this actually happens, it provides an opportunity to develop an innovative nature-inclusive agricultural system to maintain (to a certain extent) natural biodiversity.

6 Case study: poultry options as protein source in Egypt

6.1 Introduction

Many countries are facing significant socio-economic and environmental changes which may affect food security. This is especially the case in water-scarce countries such as Egypt where population growth, dietary changes and climate change may cause severe threats to food security. Addressing these issues from a water perspective in an early stage helps to prepare these countries facing the unavoidable changes and may even identify new (market) opportunities. In this Egypt case study, the water valuation framework is therefore used to identify options to address these changes, looking specifically at the poultry sector (as a main protein source).

6.2 Food and water system challenges

Egypt is a water-stressed country (117.3 according to FAO, 2016) although the country receives at least 55.5 billion cubic metres (BCM) of Nile water annually according to the Nile Treaty of 1959. Nevertheless, the large number of inhabitants along the Nile river and the Delta and the intensive agricultural withdrawals (106% of total renewable water sources which indicates reuse of wastewater FAO, 2016) are main reasons for the water-stressed situation in Egypt. This situation is likely to increase as the population is expected to grow from 92 million people in 2015 to over 151 million people in 2050 (FAO, 2017). During this time period, the urbanisation rate is forecasted to expand from 43% to 57% and GDP per capita is expected to grow from USD4,000 to USD20,000 (FAO, 2017). These socio-economic developments usually have implications on dietary patterns of the population as more urbanisation and higher income results into consumption of higher quality foods such as meat, milk and eggs (FAO, 2017). FAO (2017) estimates that poultry demand in Egypt will therefore rise with a stunning 1,100% from 100,000 tonnes in 2015 to 11,000,000 tonnes in 2050. Other livestock demand is also expected to increase significantly. The problem with the increasing livestock demand is that expansion potential of agricultural lands for poultry (and other livestock) feed is limited mainly because especially in water-scarce countries crops will compete for water and hence choices need to be made by the government.

In 2015 Egypt reused some 10 BCM of agricultural drainage and wastewater (Omar and Moussa, 2016), which could be seen as a proxy for water shortages, while it consumes 2.4 BCM of non-renewable groundwater sources on an annual basis (Omar and Moussa, 2016) which is not sustainable in the long term. Thus, Egypt relies increasingly on imports of food and feed commodities to meet the growing demand. This pattern is already visible for animal feed sources like maize and soya bean oilseed as imports increased from 3,687,000 and 145,000 tonnes in 1998 to 10,000,000 and 4,750,000 tonnes in 2021 respectively (IndexMundi, 2021). Other seed products show (although to a lesser extent) similar patterns. Byrne (2019) for example found that import as well as local production of yellow maize is related to new investments in poultry feed mills which are required to produce sufficient feed for the growing poultry production. Considering the multiple developments in Egypt's food system and the increasing water stress, the country needs to look critically at current agricultural production processes and should analyse potential measures to meet the (future) poultry and livestock - protein - demand in a sustainable way.

6.3 Poultry production options

With the expected rise in poultry and other livestock consumption, the question can be raised what Egypt could do to meet this demand. Given the current water-stressed situation, it is obvious that local production of feed stock on existing agricultural lands is not sufficient to cope with the growing demand. This could only be (partly) achieved by changing current cropping patterns. An alternative is increasing imports of animal feed. Currently, the import of agricultural commodities in Egypt is around USD 7.9bn of which 53% is used for wheat, followed by maize (19%) and soya beans (10%) (OEC, 2017). These imports could potentially be increased. However, other options could be considered as well. As there are multiple potential options, this case study focuses on alternatives within the domestic poultry value chain.

The water valuation tools can help to identify the best option(s) and may thus help the Government of Egypt with their (future) strategies to meet growing livestock demand by re-assessing the domestic poultry value chain. Moreover, this case may serve as an example for other countries depending largely on food and feed imports.

The following options, based on the water scarce situation in Egypt, can be considered:
1. increase import of animal feed sources (e.g. maize, soya bean) to meet growing poultry demand
2. increase import of processed poultry products such as chicken fillets and eggs
3. invest into alternative animal feed options such as algae nurseries or insect farms
4. agricultural land conversion: increase local production of livestock feed (maize, soya beans, etc.) on existing agricultural lands (or reclaim more lands if water can be more efficiently used)

It should be noted that the presented alternatives are examples based on changes in the poultry and livestock value chains. Other alternatives may also be considered such as changing consumer behaviour among others. This should be assessed through stakeholder consultations in Egypt. Thus, the presented alternatives should be seen as an indicative list, not excluding other options. However, the selected alternatives are sufficient to explore how the water valuation framework may work.

6.4 Resulting changes of the options

This section qualitatively describes the benefits and costs by selecting a number of indicators that represent social, economic and environmental effects of Egypt. Several indicators can be used to reflect these dimensions, such as:
1. water footprint
2. energy footprint
3. economic implication
4. employment
5. food self-sufficiency ratio and
6. biodiversity.

These indicators also relate to the OECD triple challenge, see Chapter 2. Self-sufficiency relates to food security and nutrition, economic implication and employment relate to livelihoods and rural development, and water footprint, energy footprint and biodiversity relate to the natural resource use and climate.

6.4.1 Water footprint

The water footprint describes the amount of water needed to produce a unit of product. For water scarce regions, this indicator is important to strive for efficient agricultural water use.

The world average water footprint for chicken, eggs and beef is 4,325 m^3/tonne, 3,265 m^3/tonne and 15,415 m^3/tonne respectively (Mekonnen and Hoekstra 2012). On the other hand, the global water footprints for main crops grown in Egypt such as maize, soya bean and cotton are 294 m^3/tonne, 926 m^3/tonne and 2,227 m^3/tonne respectively (Mekonnen and Hoekstra 2011). Based on a comparison of water footprints of various crops, it can be concluded that conversion of agricultural lands from e.g. cotton and soya bean towards maize production may be the most beneficial option from a water perspective as it consumes less water compared to many other crops currently grown in Egypt. Increased import of animal feed and/or processed livestock products is expected to increase the water footprint in Egypt in total as the water footprint is the sum of internal water use plus imported virtual water (minus exported virtual water). However, virtual water imports will reduce the pressure on domestic (and scarce) water resources that would have been otherwise abstracted within the country. Domestic production of algae or insects as a source of animal feed requires water resulting from evaporative losses from the water system. As such it is expected to have a small but negative impact on the country water footprint (which means a higher water footprint).

From a national water footprint perspective, the shift from high water consumption crops to animal feed crops is beneficial if maize is grown. Increasing imports of both animal feed and processed livestock products increases the national water footprint (due to virtual water import) but has a positive impact with respect to water-scarcity reduction within Egypt. The development of insect and algae farms within Egypt will slightly increase pressure on available water sources.

6.4.2 Energy footprint

The total greenhouse gas emissions of Egypt in 2012 was 288 MT CO_2e of which around 29 MT from the agricultural sector (USAID, 2015). In addition, the net CO_2e emissions from total imports were around 11 MT (CarbonBrief, 2014). Approximately 12% of the import value is from bulk agricultural imports (wheat, maize, soya beans, etc.) while 8% is caused by processed foods and animal products (OEC, 2017). Considering energy footprints is important within the scope of international momentum to address climate change.

Increasing imports of animal feed and processed livestock products will automatically result into higher CO_2e emissions born from imports in Egypt. Considering the energy footprint of Egypt only, the import of processed poultry products is however encouraged above importing animal feed. This is due to the Feed Conversion Ratio (FCR) of feed to meat which may be around 3 for poultry. This implies that for one kilogram of poultry, around 3 kg of feed need to be imported. As such, importing animal feed requires larger volumes than importing processed poultry products to generate the same amount of poultry products. Consequently, more shipping is required when importing animal feed, which results in higher GHG emissions.

Agricultural land conversion towards increased animal feed production is not expected to significantly change the national agricultural energy footprint. It is assumed that many agricultural processes leading to CO_2 emissions (local transport, production process) will be similar regardless of cultivated crops. Further, a transition towards animal feed production would lead to increased imports of currently cultivated crops (vegetables, etc.). However, it would at the same time reduce the need to import animal feed. As such, the net CO_2e emission is expected to be neutral from an Egyptian energy footprint perspective.

Particularly cultivation as a source of animal feed may have a positive effect from an energy footprint perspective. Due to photosynthesis processes of algae CO_2 is transformed to animal feed which is consumed by chicken. This is therefore an example of a circular agricultural system.

From an energy perspective, increased import of animal feed is inefficient due to large required quantities to meet national poultry demand. Increasing import of processed poultry products requires lower quantities compared to animal feed but will nevertheless result into more CO_2e emissions from imports. The agricultural land conversion will not affect the energy footprint. Domestic production of algae on the other hand may be beneficial from an energy perspective as it is a good example of a circular agricultural system that requires fewer or no inputs at all.

6.4.3 Economic implications

From an economic perspective the comparison between the price of imported versus locally produced chicken is relevant to identify the most cost-efficient market option to meet local chicken demand. Based on the volume of imported chicken of 222,000 MT for a total value of USD 325m in 2017, the unit price for imported chicken is around USD 1,500 per tonne (Knoema, 2017; OEC, 2017). This figure is in line with an online new article which reports imported chicken prices between USD 1,500 and 1,600 per tonne (Eldin, 2016). In comparison, the price of locally produced chicken is USD 1,200 USD/tonne (Eldin, 2016). Thus, local production (including imports of poultry feed and local value chain processes) is cheaper compared to importing the end-product. This also suggests low import prices for animal feed. Further research is required to estimate the effect of algae/insect production as chicken feed on the market price of chicken.

The conversion of existing agricultural lands from e.g. vegetables and cereals towards crops used as chicken feed (maize, soya beans) would allow for local expansion of chicken production and thus reduction of imports of chicken and/or feed. Large-scale conversion of existing agricultural lands is the only way as developing new agricultural lands is difficult due to water scarcity. However, large-scale conversion would also imply increased import needs for vegetables and cereals (that are substituted for feed production). Moreover, income of farmers is likely to decrease - or needs to be compensated by the government - as animal feed results in lower revenues compared to various cash crops currently cultivated in Egypt. As such, conversion of existing agricultural lands towards animal feed crops is not expected to have a positive impact on the national economy.

In summary, the import of poultry products is more expensive than local production (even when feed is imported) and thus negatively judged from an economic point of view. On the other hand, import of animal feed is positively judged due to relative low market prices. Agricultural land conversion has an overall negative economic impact while economic impacts of algae/insect need to be further assessed.

6.4.4 Employment

Egypt's poultry sector employs around 2.5 million workers and produces 1.25 billion day-old chicks, 1.1 billion broilers and 8 billion table eggs per year (Byrne 2019). Large commercial breeders in Egypt account for about 70% of the total poultry production (Byrne 2019). From an employment point of view, maintaining and expansion of local poultry production is beneficial. Thus, strategies focusing on increasing feed imports (maize and/or soya beans) and production of algae as alternative chicken feed are positive for local employment as they stimulate the national poultry sector. In addition, algae and insect farming may even provide additional employment opportunities as they create new business opportunities. Conversely, the import of chicken products itself may be less beneficial for employment within Egypt as labour intensive parts of the poultry value chain (feed production & processing, chicken farming, slaughtering) are carried out abroad.

The agricultural land conversion option towards more chicken feed production is not expected to significantly affect employment. On the one hand the conversion would stimulate the local poultry value chain but on the other hand it simultaneously reduces labour opportunities of existing agricultural value chains based on current production.

In summary, both stimulation of poultry feed and especially algae/insect farming are positive from an employment point of view because they maintain and expand jobs in the poultry value chain. On the other hand, the import of processed poultry products has negative impacts on employment compared to the previous options while agricultural land-use conversion has a neutral outlook.

6.4.5 Self-sufficiency

Autonomy in feed and food production for Egypt's poultry sector may be beneficial for a number of reasons including reduced vulnerability of external shocks in the international trade market. Examples of these shocks were visible in 2007-2008 when food riots broke out in more than 30 countries due to increased import prices of agricultural commodities including wheat, maize, rice, etc. (Financial Times, 2011). In this context, the import of both animal feed and processed livestock products from other countries is not beneficial as it creates a dependency on international trade fluctuations which Egypt and most other countries have limited influence on. In the end, both options create potential risk for civil unrest in the country. Agricultural land conversion towards poultry feed has a neutral impact as more poultry self-reliance is compensated by increased dependency on other crops. As such, it does not influence dependency on agricultural commodities from other countries. Local production of algae and other alternative ways to develop poultry feed is beneficial as this contributes towards a self-reliant poultry sector in Egypt.

In summary, the development of algae/insect farming as alternative feed stock for poultry is the best way for Egypt towards increasing self-sufficiency in food production.

6.4.6 Biodiversity

Egypt has a wide variety of habitats with microclimates that are home to plants and animals representative for Mediterranean, tropical and desert environments. Over 90% of Egypt's biodiversity is represented by arid and semi-arid ecosystems with oases as the most outstanding features and the main sources of water and vegetation (SIS Egypt, 2020). The Siwa Oasis agro-ecosystem for example is home to 154 specifies of which 52 are cultivated species (El-Saied et al., 2015). The development and expansion of modern irrigation schemes across arid environments have radically transformed both natural environments and existing agricultural systems over the past century (El-Saied et al., 2015). The transition towards high-yielding varieties in agriculture caused a reduction of local varieties as main cultivation is focused on wheat, maize, cotton and rice. If Egypt would focus on domestically increased animal feed production with a lower water footprint compared to currently grown crops such as cotton, it could reduce pressure on the already limited water resources in oases and thus positively affect biodiversity in oases. Also the import of animal feed and/or processed livestock products is encouraged as it does not compensate for the local biodiversity. The production of alternative animal feed sources such as algae production is on the one hand positively judged from a biodiversity perspective as it may provide scope for development of new agriculture or aquaculture habitats. On the other hand, it may cause water quality issues and compromise the currently presented aquatic biodiversity. As such, the alternative feed production from algae and insects has a neutral outlook from a biodiversity perspective.

In summary, the import of animal feed and processed poultry products is positively judged as it does not put further pressure on Egypt's biodiversity. However, transition of agricultural lands to animal feed crops consuming less water compared to various presently grown crops may be the most beneficial option as it reduces pressure on oases in particular. Algae and insect farming have a neutral outlook with respect to biodiversity.

6.5 Description of costs and benefits

This section describes the trade-offs (benefits versus costs) of the four options compared to the BAU situation of poultry production in Egypt. The BAU situation in Egypt is in fact a mix between on the one hand importing animal feed and processed poultry products while on the other hand encouraging domestic production of animal feed. It is moreover assumed that in the BAU situation investments into alternative animal feed production do not exist on an industrial scale.

The four options should be regarded as 'extreme' options. For option 1 this implies poultry raising through 100% import of animal feed, or in other words no domestic production of poultry feed anymore. For option 2 it means 100% import of processed poultry products and thus no domestic poultry value chain. For option 3 it implies that all animal feed will be borne from alternative sources (e.g. insects and algae) while for option 4 it means that agricultural land will be converted to animal feed as much as needed to fulfil the domestic poultry demand.

Each option has certain country-specific benefits and costs based on parameters extracted from the OECD Triple Challenge. The animal feed import option is positively judged from a livelihood and rural development perspective as it creates business opportunities for poultry raising and processing industrial activities. However, the main trade-off is not being a self-sufficient food security country due to full dependency on imported animal feed to maintain the poultry sector. The effects of this option on resource use and climate change have an overall neutral outlook. On the one hand, effects on Egypt's energy footprint are expected to rise due to transport (which is negative) while on the other hand the animal feed import option reduces pressure on its scarce water resources which is beneficial, also in the context of preserving natural ecosystems like oases.

From the processed poultry import option perspective, the trade-offs are mainly similar to the first option. However, an additional trade-off is the potential loss of employment as the entire poultry raising and processing activities will be done in other countries.

The most positively judged option based on a qualitative assessment is investing in alternative animal feed sources, such as algae and insects as these provide benefits to almost all indicators. It helps in achieving a more self-sufficient food system while at the same time generates new business opportunities. Compared to BAU, water and energy usage may be lower with this alternative although more investigation is required to confirm this.

The main benefits of the agricultural land conversion option include reduced pressure on water resources (in case maize is grown as fodder) which is also beneficial for natural ecosystems. This option has a neutral score on the self-sufficiency level as increased domestic animal feed production would be added to the cost of other agricultural products which then need to be imported. The main trade-off lies with the livelihood and rural development indicator as animal feed generates less income (per m^3 water) compared to vegetables and fruits.

6.6 Link with Triple Challenge and VWI

The OECD Triple Challenge objectives are used to identify benefits and costs of the options when compared to the BAU situation. The Triple Challenge objectives and the indicators as presented in the previous section are related as follows:

1. Food security and nutrition – self-sufficiency, import/export balance.
2. Resource use and climate change – energy and water footprint, biodiversity.
3. Livelihoods and rural development – employment, economic implications.

Table 6.1 presents the impacts of the four options.

Table 6.1 *Impact of the options on food and nutrition security, resource use and climate change and livelihoods and rural development based on the OECD Triple Challenge dimensions*

Policy option	Food security and nutrition	Resource use and climate change	Livelihoods and rural development
I: Import animal feed	-	0	+
II: Imports of processed poultry products	-	0	-
III: Investing in alternative animal feed	+	0	+
IV: Agricultural land conversion for feed (maize)	0	+	-

Legend: 0 – no effect, - negative effect, + positive effect.

Link with valuing water principles:
As this case study describes an ex-ante analysis, this section describes how the VWI principles can be applied.

- **Principle 1**. *Recognise and embrace water’s multiple values*. The water-scarce situation in combination with a growing poultry demand in Egypt can be addressed in various ways. However, this case study is particularly focused on options related to the poultry value chain. Although the options do not directly propose changes in the water system itself, the scarcity of this resource is the underlying reason that options should be developed to meet the growing poultry demand. Moreover, each option will differently impact the available water resources in Egypt as well as other socio-economic conditions. The benefits and costs of these options have to be assessed through consultations with both public and private sector to recognise the multiple values of water for different parties.
- **Principle 2.** *Reconcile values and build trust.* The public and private stakeholder assessments will have to be done in a way that opinions on options and associated benefits and costs can discussed openly with each other.
- **Principle 3.** *Protect the sources.* All the options are focused on reduced water use in the poultry value chain within Egypt. The main aim is to contribute to secure sufficient water for multiple uses including for drinking, industrial use and agricultural production, prevent depletion of fossil groundwater reserves and maintaining ecological values within the country.

- **Principle 4.** *Educate to empower.* Presentation of current practices in the poultry sector and associated water problems and discussion of various options to address this issue, creates an unique opportunity to raise awareness by both public and private stakeholders on the key role and value of water in Egypt.
- **Principle 5.** *Invest and innovate.* Except for option two, significant investments are required in infrastructure, knowledge development and production processes. In this context, it is important to develop an investment plan to identify (inter)national financing sources. In case option 3 is selected, it creates opportunity for finding an innovative solution to increase poultry demand on a self-sufficient way.

7 Discussion and conclusions

7.1 Discussion

The Food and Water Valuation Framework is developed to improve decision making within the food system which involves crucial roles for water and water management. The FWVF combines the food system approach and the valuing water concept. Based on four case studies, we have shown the value added of the four steps distinguished by the FWVF. In all cases, water and water management play a key role in the food system, and we analysed this role based upon the water valuation aspect. Within the FWVF, the valuation of water is not limited to the direct impacts of water on agriculture or food production but it considers all aspects of the food system (similar to the OECD Triple Challenge dimensions).

The case studies differ across temporal and spatial dimensions. In the two ex-post cases, the Coca Cola case (Chapter 3) and the freshwater pipeline case (Chapter 4), based upon literature we analysed how the value of water was used for selecting the preferred option from the potentially available options. In fact, using the FWVF to describe these ex-post cases shows that elements of the Food System Approach and Valuing Water were not applied to the full extent in these assessments. Use of the FWVF in these two cases would lead to a more systematic approach. The analysis of the Jordan case (Chapter 5) and the Egypt case (Chapter 6) are ex-ante analyses (formal ex-ante studies are not available yet) and these were used to analyse whether use of the FWVF would provide more insights in the optimal policy option for change in the food system. The fresh water pipeline case also contains an example of exploring solutions for current challenges in an adjacent region of the pipeline (Section 4.3). These cases provide opportunities to explore the potential use of the FWVF in answering water allocation questions at different levels.

For all cases, we assessed the four FWVF steps. In the first step, we identified the problems and challenges with respect to the food system and water system. The FWVF determines in this step which elements (e.g. drivers, impacts) are relevant or important in each case. Depending on the location and the decision-making actor (who will select from the different options identified) different segments of the food system approach are relevant. In the next step relevant options to solve the problems are identified. More diverse options are identified if the FWVF is applied, compared to the water valuation framework, because also measures that do not affect the water basin directly can be taken into account (see the Egypt case study). In the third step we assessed the positive and negative impacts of the options in the water and food systems. Finally, the impacts were valued allowing incorporation of different values of water. Based on this step, we assessed the trade-offs between options for change in the water and food system. Obviously, the clearer the impacts can be identified and quantified, the more transparent the assessment will be.

The four cases were selected in such a way that in all cases the shortage of (good quality) water of the desired quality at the desired moment would be of importance:

- In the Coca-Cola case the FWVF added options in the food system, increasing water efficiency within the food chain (possibly more than one water basin involved), to the standard approach towards increasing water efficiency of the production plant. Coca-Cola had done so already due to pressure from local water users and environmental NGOs.
- Zeeland (NL) has favourable growing conditions for pears. However, availability of good quality fresh water in early spring and during growing season is important to prevent damage due to spring frost and summer droughts respectively. In the pipeline for high-value crop (pears mainly) case study, the FWVF adds the importance of livelihood to the valuation process of the water company that distributes the water from the pipeline.
- In the Jordan case (food security in light of population growth, water scarcity and climate change), the FWVF shows different elements of food security in a water context (e.g. self-sufficiency, livelihood) which enter the trade-off. Valuation of all elements is not easily done.
- The Egypt case study deals with protein security in light of population and welfare growth and water scarcity due to climate change and upstream developments in the Nile Basin. The FWVF brings alternative

protein sources into the picture, which could reduce water use enormously, but also brings in the question whether to raise chickens in Egypt or abroad from a water valuation perspective. Applying the FWVF has provided more alternative options than if the focus would be on valuing water alone.

Link with Water Valuation Initiative and the OECD Triple Challenge
The advantage of the FWVF over VWI is that the FWVF adds the entire food system to the analysis, which allows for a broader spectrum of options to solve water issues. With the Food System aspects incorporated in the FWVF, the assessment of water use and water valuation is broadened. In the ex-post Coca-Cola case and the fresh water pipeline, application of some of the VWI principles could be (implicitly) checked. Except for the principle 'Educate to empower', all principles were (to some degree) present in the Coca Cola case (see Section 3.5) and the fresh water pipeline (see Section 4.4). For the ex-ante type of case studies, the WVI principles are used to draw the activity plan to elaborate the measures and implement the optimal one (Jordan and Egypt case studies).

For all options analysed in the case studies, we assessed the link with the relevant elements of the OECD Triple Challenge: food security, resource use and climate change as well as livelihoods and rural development. Implicitly or explicitly, these challenges were addressed in all cases. The FWVF is linked to the OECD Triple Challenge as follows:
- OECD Triple Challenge's Food security and nutrition corresponds with food security in FSA
- Resource use and climate change is part of the FSA environmental outcomes
- Livelihoods and rural development are incorporated in the FSA social and economic outcomes, livelihood is also part of food access.

In the Coca Cola case, food and nutrition security was not the main goal, while resource efficiency (cost reduction) and livelihood strategies were. The fresh water pipeline will contribute to more nutritious food, because it enables to grow pears and high value vegetables, however the main driver of change in this case study was the security or improvement of the livelihoods and rural development by ensuring economic activity and employment.

7.2 Conclusions and recommendations

Main findings on suitability of the Framework:
The FWVF integrates the FSA and water valuation frameworks. The advantage of the FWVF over the valuing water initiative is that its focus is not solely on water-oriented solutions (e.g. improving the water efficiency), but also other options to increase food security without a direct water angle come into the picture (e.g. vegetable sources of protein in Egypt).

The Food System Approach enables a holistic approach with respect to food security issues. It does not contain explicitly a tool which facilitates valuation or making trade-offs, it merely stresses all relevant elements and drives of the food system affecting (directly or indirectly) food security. As food security is a multi-dimensional indicator, the FWVF enables transparent trade-offs between indicators like livelihood, natural resources and water efficiency in food production. The FWVF brings valuation (tools) from a water perspective into the picture and combined it provides insight into questions as whether to produce valuable crops for export, or to grow staple crops for national consumption.

The framework is useful to assess and quantify both benefits and costs to identify trade-offs in water allocation choices and food security issues. It provides an integrated analysis which considers benefits and costs on economic/financial (costs of investment, economic effects), sociologic (employment, livelihood, etc.) and environmental (biodiversity, climate change) levels.

As such, the FWVF is specifically relevant to answer water allocation questions in water scarce countries, such as Jordan and Egypt, where food security is an issue. In both countries, water allocation options provide several benefits and costs on socio-economic and environmental conditions which are all considered under this framework. In non-water stressed countries, however, other issues such as air pollution, climate change, etc. may be the most crucial factors with respect to agricultural development. Being an integration framework, it should be elaborated to enable a focus on the relevant issues for countries that are less water stressed.

A framework to assess the value of food security does not yet exist. Such a framework will be extremely useful to design and select options to improve the value of water and food security simultaneously.

Recommendations (general)
The FWVF is a first step in emphasising more explicitly the value of water within the FSA, which is not limited to the water system or water cycle. The FWVF can be elaborated upon although a generic methodology that will fit all situations will not be desirable, because it will be too complex and it will reduce its fit with the valuing water initiative principles. The FWVF may provide a conceptual framework for other 'resource elements' in the FSA as well.

Recommendations for the Dutch Ministry of LNV
The Ministry of LNV could use the outcomes of this study to strengthen its role in supporting countries to improve their agricultural policy based upon valuing water in the broader context of the food system. It is recommended that the Ministry initiates activities in their focus countries to achieve this objective as follows:
- Elaborate on the Jordan and Egypt case studies as presented in this study through conducting regional/national stakeholder workshops to identify all possible options and indicators to solve water scarcity problems and using the valuing water framework to assess these options.
- Propose the application of the valuing water framework in other priority countries of the Ministry of LNV.
- Assess possibilities to use the framework in identifying best options for international trade between countries (virtual water).

Corporate food and beverage firms can play an important role in reducing water scarcity, as they oversee a large part of the supply chain and can make arrangement with other stakeholders in the food system. They might be an efficient starting point for policies to increase water efficiency in the food system.

To improve on water efficiency it is encouraged to invest into feasibility studies on enhancing protein supply in drought-prone countries, which are not self-sufficient in protein production. In such regions, protein production is challenging due to relatively large water demand while resources are limited. However, different options are possible (e.g. algae and insects as animal feed source) which need to be further assessed. The water valuation framework can be applied in this context, to investigate which option to enhance protein supply may generate highest value of water.

In the case of the fresh water pipeline for high-value crop farmers in Zuid-Beveland, the expansion of the fresh water pipeline (i.e. increase the current capacity to supply fresh water) could be analysed further by the province of Zeeland, the Regional Water Authority, Evides (which operates the water pipeline), and the farmers. For the Ministry this fresh water pipeline can have interesting interaction with its policy agenda.

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Annex 1 Map of the fresh water pipeline

Figure A1 presents the Southwestern Delta and indicates the infrastructure of the fresh water pipelines exploited by Evides (see blue dotted line).

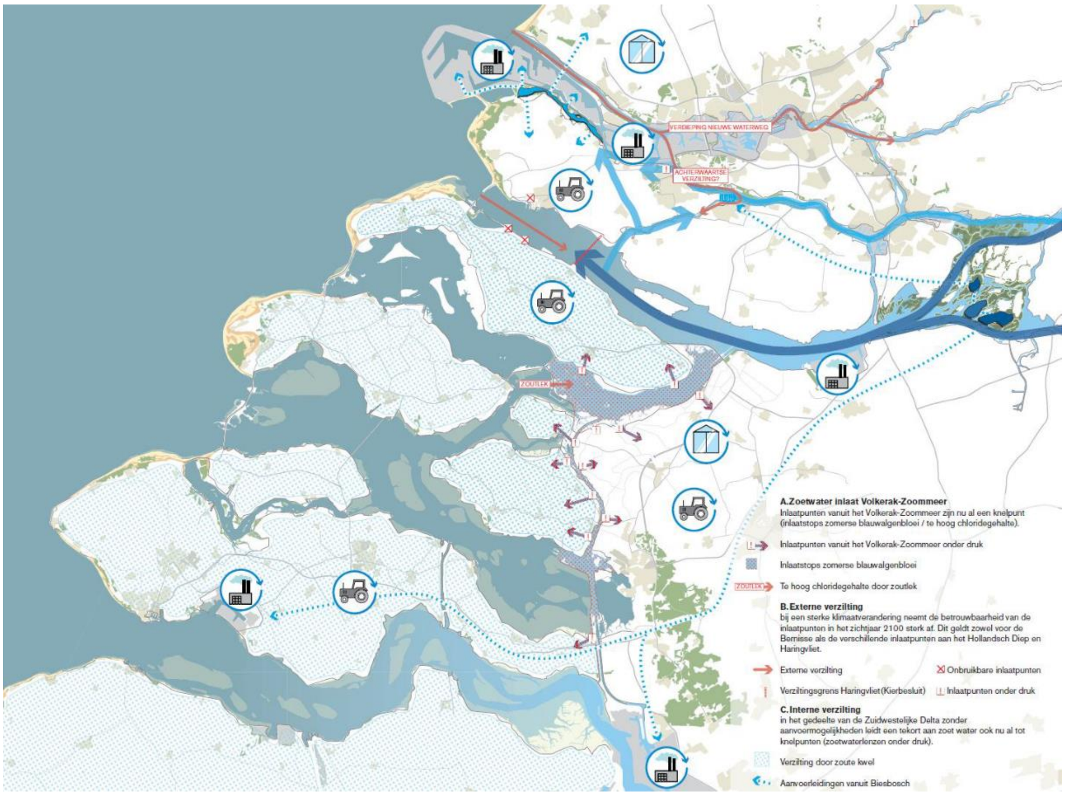

Figure A1 *Map of the fresh water pipeline (blue dotted line) in the Southwestern Delta of the Netherlands (Bestuurlijk Platform Zoetwater 2014)*

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