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Stakeholder perspectives for switching from rainfed to irrigated cropping systems at high latitudes

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ABSTRACT

A growing scarcity of freshwater supplies threatens societies and their future wellbeing as demand for water in agriculture increases. Water deficit often interferes with crop growth in temperate regions. However, between season and within season spatial and temporal variations in precipitation are high. Finland has abundant, good-quality freshwater resources, but only 3% of arable land is irrigated, almost exclusively for horticultural production. We invited 14 stakeholders to participate in a panel to generate and evaluate potential strengths, weaknesses, opportunities and threats (SWOT), focusing on future needs, means and restrictions of agricultural water management systems in Finland. During the panel meeting the expert members considered relevance, strategies and timescales for development and implementation of irrigation systems and characterized six strengths, seven weaknesses, 11 opportunities and six threats. Opportunities received the highest general priority. The SWOT results are further considered in this article from the viewpoints of readiness to operate, justifications for viability of implementation of water management systems and institutional and socio-economic drivers and limitations. The stakeholder perspectives encourage us to take the initial step to open the dialogue with policy makers with a clear message that the numerous management options should be explored in the near future in order to develop a solid strategy to either shift from rainfed to irrigated arable farming or not.

Introduction

Anthropogenic activities are the primary drivers of global land use changes (Wheater and Evans, 2009) and irrigated agriculture is globally the largest user of water resources (Portmann et al., 2010; Brauman et al., 2013). In many regions agricultural practices have adverse effects on the environment, being a main source of suspended solids in and nutrient loads to water systems (OECD-FAO, 2009).

Societies need to address the increasing challenge of producing more food, feed and fuel, which means increasing agricultural production either through expanding the area of arable land, increasing yields per unit land area and/or changing consumer habits (Licker et al., 2010). Expanding the agricultural area would mean deforestation and loss of carbon sinks in addition to other potential detrimental effects on ecosystem goods and services. Hence, to produce more per unit land area means that agricultural systems need to be sustainably intensified to couple increases in productivity with environmental benefits (Fedoroff et al., 2010; Soussana et al., 2012). Increasing agricultural productivity without mitigating or halting increased environmental pressures on aquatic systems threatens the sufficiency and ecological status of surface and groundwater resources (Green et al., 2011). When limited only to the agriculture–ecosystem framework, conflicts are already likely and depending on the region compromises are inevitable when searching for a balance between various objectives and policies governing food production, adaptation to and mitigation of climate change, land use changes, water resources and their management as well as environmental protection (Weatherhead and Howden, 2009; Licker et al., 2010). Regardless of emphasis, the outcome has to be acceptable to different stakeholders. This means that the sustainability targets will be broadly covered and that developing agricultural systems for the future has to deliver on the multiple aims of sustainability and environmental soundness while being socially acceptable and economically viable (Soussana et al., 2012).

According to projections, climate change is likely to have profound negative effects on water availability at the global level and especially so in the currently arid regions like southern Africa, Central America, Western Australia and Mediterranean regions (IPCC, 2007). Some of the most considerable and direct impacts of climate

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change over the next few decades are anticipated to be on agricultural and food systems (Brown and Funk, 2008; Lobell et al., 2008; Battisti and Naylor, 2009). Adaptation is the key factor to shaping the future severity of climate change impacts on food production (Lobell et al., 2008). Despite the ability to moderate negative impacts of climate change through relatively inexpensive changes in cropping systems, the greatest benefits are likely to result from costly water management measures, including irrigation (Lobell et al., 2008). Hence, irrigated areas are likely to expand in the future (Neumann et al., 2011).

Managing water resources better in the future is a key component of sustainable intensification of agriculture. Water scarcity, characterized by high spatial and temporal variability and inefficient water use, is the principal reason for yield losses, low input use efficiencies and excess nutrient loads to the environment (Brauman et al., 2013). As climate variability and extreme weather events are expected to be more frequent in the future (IPCC, 2012), development of cropping systems needs to contribute to controlling crop responses to prevent crop failure, maintain soil structure and infiltration rates and protect water resources and hydrological processes (Weatherhead and Howden, 2009).

Water deficit is frequently experienced in Finland, which represents Europe's northernmost agricultural region and has high annual precipitation. After snow melts in spring, soil needs to be dried with drainage systems to facilitate sowing. Seasonal and within season spatial and temporal variations in precipitation challenge field crop production (Peltonen-Sainio et al., 2011a) similarly as in the UK (Weatherhead and Howden, 2009). When averaged over the years 1970–2000, only 30–50% of the rainfall needed for undisturbed yield formation of spring barley (*Hordeum vulgare*) was available in the prime cereal production region of Finland, resulting in up to 17% average yield loss across years (Peltonen-Sainio et al., 2011a). Due to frequent drought caused by insufficient precipitation to meet the crop needs in early summer, the Finnish growing season has an exceptionally low number of effective growing days (Trnka et al., 2011). Even temporary water scarcity, if occurring at a critical developmental phase of the crop, is detrimental for yield formation as under long day conditions developing plant stands have little capacity for compensation (Peltonen-Sainio et al., 2009a). Hence, drought as a single factor is the most frequent weather constraint hampering crop production in Finland. During 2002–2003, 1400 farms, many with livestock, suffered from severe water scarcity in Finland. Over 64,000 m^3 of water was transported to farms, at an average cost of €5/m^3. Also yields were low and some 20–40% of autumn sowings were re-established. Additional costs to agriculture alone in the severely affected south-western region were nearly €10 M (Silander and Järvinen, 2004). Wheaton et al. (2008) reported even harder lessons for Canadian agriculture from drought experienced in 2001 and 2002.

Increasing scarcity of freshwater supplies will be the dominant element threatening societies and their wellbeing globally this century. Demand for water in agriculture will continue to increase (Kanwar, 2010; Neumann et al., 2011), agricultural production in irrigated regions is becoming more water-constrained (Qureshi and Neibling, 2009) and according to the worst scenario, even vast areas of drought-prone arable land may be withdrawn from agricultural production (IPCC, 2007). In contrast to these patterns, northern Europe may receive an increased amount of annual precipitation in the future (Jylhä et al., 2004; IPCC, 2007) and yield potentials could increase even markedly due to longer growing seasons (Olesen et al., 2011; Peltonen-Sainio et al., 2014a). However, also in the northern temperate regions distribution of precipitation and spatial, and temporal variations in it, are expected. Even in cases when climate change models project a slight increase in precipitation during the growing season (Ylhäisi et al., 2010), the increase will probably be too small to compensate for the needs of greater crop biomass and the increased evapotranspiration in increasingly warm conditions (Peltonen-Sainio et al., 2014a). Furthermore, projected increases in precipitation outside the growing season challenge overwintering (Peltonen-Sainio et al., 2009b, 2011b) and soil drainage and represent a higher risk for nutrient loads, erosion (Puustinen et al., 2007), and could also increase the risk of soil compaction and poor soil-bearing capacity. Likewise in the UK, due to less water in the summer season and abundant rainfall in winter, climate-change-induced risks for erosion and pollution will be higher and could adversely affect surface water quality (Weatherhead and Howden, 2009). Depending on the region groundwater systems and resources may also be threatened, due to severe drought spells (Green et al., 2011).

Finland has abundant, good-quality freshwater resources. Irrigation is only practised on 3% of arable land (Table 1) however, including both sprinkler and drip irrigation, depending on the target crop (Suppl. 1). Most often surface water from a waterway extending beyond the farm is used for watering (Suppl. 2). Irrigation is common in horticulture, where the share of land area available for irrigation is reasonably high, one third of the total horticultural production area. However, in contrast, field crop production is virtually all rainfed, potato being the only occasionally irrigated crop. Irrigation is typically used to mitigate harmful effects of drought, and frost in the case of berries, fruit and potato (Table 1). Hence, it is economically feasible to irrigate only the high value cash crops as the price of yield increase covers the irrigation costs. Controlled drainage and sub-irrigation are options to improve the field water management but these methods are not employed on a large scale in Finland. The controlled drainage area was about 30,000 ha, i.e. less than 1% of the arable area in Finland in 2012 (Koikkalainen, 2014).

Concerning field crop production, irrigation equipment is outdated, originating mainly from the 1970s and 1980s. Solving the current, and more importantly the future, constraint of water limitation at the critical phases of the growing season calls for development of modern water management systems that not only focus on enhancing productivity but also on protecting the environment from climate-variability-induced risks for nutrient loss. In the vulnerable Baltic Sea area the expected future changes in precipitation, snowmelt, and river runoff will have detrimental effects on the ecological status of seawater through eutrophication. It is thus necessary to continue to improve measures to halt eutrophication by further reducing waterborne nutrient inputs (HELCOM, 2007).

Marshall et al. (2013) stated that "adaptive capacity is the human potential to convert existing resources into successful adaptation strategy", and in this study we aimed to benefit from such a potential by inviting stakeholders to participate in an expert panel to generate and evaluate potential strengths, weaknesses, opportunities and threats (SWOT analysis), focusing on future needs, means and restrictions of agricultural water management systems in Finland. We used SWOT analysis as a planning tool when weighting rationales and considering whether or not to progress by consulting with policy makers prior to progressing with development of modern water management systems tailored for the particular needs of the northernmost agricultural regions of Europe and taking into account the special conditions of the region.

Materials and methods

SWOT analysis is a commonly used planning tool (Kurttila et al., 2000; Pesonen et al., 2000). Despite being well-known and widely used it has some weakness, particularly that it can be subjective and analyst-dependent. Consequently we based our SWOT analyses on the output of an expert panel where stakeholders differed in their backgrounds. The panel comprised 14 experts