



Nordic agriculture under climate change: A systematic review of challenges, opportunities and adaptation strategies for crop production



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ABSTRACT

The Nordic countries' agricultural sector is potentially considered both a winner and loser in relation to climate change. With effective adaptation management, climate change could lead to increased agricultural productivity. Yet if concurrent challenges are left unaddressed, productivity losses may impede gains. Thus, adaptation to climate change is key both to avoid negative consequences and to benefit from opportunities. This paper conducts the first systematic literature review of scientific and grey literature on climate change related opportunities and challenges in Nordic agriculture, resulting in a complex overview of required adaptation actions. The synthesis on suggested adaptation policies and measures shows that farm based adaptation measures appear to be more abundant and more discussed than policy driven adaptation in the scientific literature. This paper identifies a knowledge gap regarding the complexity of adaptation needs and trade-offs in the Nordic agricultural sector. In conclusion, although the agricultural sector in the Nordic region is facing certain benefits from climate change, this review demonstrates profound challenges related directly to climate change. The synthesis of suggested adaptation actions furthermore indicates that adaptation involve trade-offs, however, increased knowledge on this subject is required. Failing to address these challenges might impede Nordic agriculture's potential gains from climate change in a long-term perspective.

1. Introduction

Nordic agricultural production is relatively small. The total wheat production of the Nordic Countries (Denmark, Norway, Sweden, Finland and Iceland) corresponds to only 5% of the total European wheat production (FAO, 2015), despite being one of the main cultivated crops. Climate change is generally anticipated to increase the food production potential in the Nordic countries (e.g. Maracchi et al., 2005; Olesen et al., 2007), and the degree to which climate change may cause increases in future agricultural production has even been equated to that of liberalization and trade (Fogelfors et al., 2009). Nevertheless, in the near future, agricultural policy and market conditions are anticipated to influence the Nordic agriculture to a greater extent than climate change (Jordbruksverket, 2017; Juhola et al., 2017; Woods et al., 2017). Even though the prospects for future Nordic agriculture and their inter-linkages with climate change are highly complex, the relative importance of Nordic agriculture in global food production is likely to increase in the future (Fogelfors et al., 2009).

While many consider Nordic agriculture a potential winner of climate change, others stress the challenges for the region. On the one hand, if managed properly, climate change is projected to have positive effects on agricultural productivity (Olesen and Bindi, 2002; Rötter

et al., 2011), while on the other hand, agricultural production will face climate change induced challenges requiring adaptation (Olesen et al., 2011). The existing scientific and grey literature, thus, gives voice to diverging perspectives on the potential for Nordic agriculture in future climate conditions.

In this context, adaptation to climate change is key, both to avoid negative effects and to benefit from opportunities. Hence, this paper understands adaptation as actions intended to reduce vulnerability to and/or take advantage of opportunities arising from current or future climate change (Burton and Lim, 2005; Howden et al., 2007). Two levels of agricultural adaptation are often discussed; farm-based measures and policy-driven adaptation, the former grounded in farmers' rational self-interests and the latter in collective needs (Iglesias et al., 2009, 2012b). Since literature reviews on agricultural vulnerability and adaptation generally tend to focus on broad regional assessments or on challenges to the most vulnerable countries (e.g. Iglesias et al., 2012b; Anwar et al., 2013; Locatelli et al., 2015), the diversity of opportunities, challenges, and various required adaptation actions are not fully captured in syntheses involving the Nordic region.

This paper is the first systematic literature review on opportunities, challenges and adaptation actions to climate change in Nordic agricultural crop production. While opportunities for Northern European

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agricultural production are often highlighted in a larger regional contexts (e.g. EEA, 2017), the study addresses the need for increased reflexivity about the geographical and socio-economic context when assessing climate change opportunities. The aim of this paper is to identify and synthesise opportunities, challenges and adaptation policies and measures from a systematic review of the scientific and grey literature on the Nordic countries' agricultural sector. Based on this synthesis, the intention is to identify important knowledge gaps within the research field of agricultural adaptation to climate change.

In section two, the analytical method of the systematic literature review is described. Section three presents the result of the review; summarising the opportunities, challenges and adaptation actions identified in the literature. Section four discusses knowledge gaps as identified in the synthesis. Section five concludes, *inter alia*, that there is a lacking amount of studies focusing specifically on adaptation in Nordic agriculture and that adaptation-induced trade-offs make it unclear how to adapt and what to prioritize.

In the following, a short background of the projected climate changes in the Nordic region is provided based on an ensemble-mean of nine of Global Circulation Models downscaled with Rossby centre's regional climate model RCA4 for the RCP4,5 scenario¹ (Strandberg et al., 2014). The projected changes described, are the differences between 2071–2100 compared to 1961–1990.

Of great importance for agricultural production is that the vegetation period is projected to start 10–50 days earlier and end 5–50 days later, depending on the region. The southern parts of the Nordic countries are projected to experience the greatest change in spring whereas Norway, southern Finland and mid-east Sweden are anticipated to have the greatest prolongation in autumn. The average temperature is projected to increase 1–3 °C during spring, summer and autumn, with different regional variations depending on season but generally the greatest temperature increase is in the northern parts. In winter, the temperature is projected to increase 2–8 °C, with the greatest increase in the very north of Norway and Sweden and northern half of Finland (6–8 °C). Mean precipitation is generally projected to remain stable or increase throughout the region, with up to 30% increase in northern half of Sweden during spring.

These projected climate changes have commonly been argued to give rise to higher agricultural production potentials (e.g. Maracchi et al., 2005; Olesen et al., 2007). Improved conditions in northern Europe are thought likely to support a shift from spring-sown to winter cereals, which will allow higher yields (Trnka et al., 2011). This was also the main message that was communicated in Swedish farming magazines in year 2000–2009, favouring opportunities rather than challenges (Asplund et al., 2013).

Nevertheless, climate change will likely involve increased weather variation and more frequent extreme weather events (IPCC, 2012). The number of days with heavy precipitation is projected to increase for the whole Nordic region with about 2 days increase per season, while the western Nordic region is projected to have an increase of up to 6 days per season (except spring). However, despite a mean increase of annual precipitation and heavy precipitation events, droughts are anticipated to be prolonged with 1–2 days per year in the very south of Sweden and Norway and all over Denmark.

The projected warmer and wetter conditions as well as more frequent extreme weather events in Northern Europe might pose a number of challenges for agriculture (Kovats et al., 2014). Extreme weather events could cause yield losses in northern Europe if effective adaptation actions are not implemented (Rötter et al., 2013). Although projections indicate that the frequency of extreme weather events will increase in Europe (Kovats et al., 2014), aspects of extreme weather events are often omitted from yield models (Rötter et al., 2012).

2. Systematic literature review

The method of this study draws on a five step approach for systematic literature review developed by Khan et al. (2003). This method of a systematic review involves framing of structured questions, identifying relevant work based on a selection criteria, structurally assessing the studies, summarizing the evidences and interpreting the findings.

The following three structured questions were specified prior to the review work and further kept in mind when reviewing the literature: (i) How is climate change influencing and projected to influence agricultural crop production and management in the Nordic countries? (ii) What challenges and opportunities are highlighted? (iii) What required adaptation actions (policies and measures) are mentioned?

The second step of the systematic literature review involves the identification of relevant publications. This study covers a substantial body of peer-reviewed articles and some essential grey literature (reports from e.g., government, public authorities, county administrative boards, and research institutes). To include as many relevant publications as possible, the search² was performed in the databases: 'Web of Science', 'Scopus', 'Agricola', 'Google Scholar', 'Environmental Sciences and Pollution Management', and 'Norart'. In addition, a Google search was conducted in the Nordic languages to cover essential national grey literature.

This initial search was performed by the Linköping University Library in 2014 and resulted in > 2000 search returns. The library conducted a first screening which resulted in a list of about 160 publications. Titles and, when necessary, abstracts, for these 160 publications were examined in order to determine the potential relevance in relation to the objective of this paper. The criteria to be included in the review were that the publication had to address one or several of the Nordic countries as well as agricultural issues in combination with climate-related impacts and/or adaptation. Iceland was excluded from the review since their agricultural production mainly is related to sheep and dairy production (Farmers Association of Iceland, 2009). The original search, which was performed in 2014, was complemented by an additional search in June 2017 to add the most recent publications. Moreover, the systematic search has been complemented with studies identified from in-text citations and recommendations. Finally, 60 studies were included in the review (see Appendix).

The literature was assessed based on the (i) regional scope of the study, (ii) identified climate related challenges, (iii) opportunities, (iv) adaptation strategies or guidelines and (v) climate change adaptation experiences. The results were further coded for each climate factor mentioned in the assessed literature and synthesised for the three categories opportunities, challenges and adaptation actions to interpret the results of the review. In order to systematically synthesise adaptation actions and identify adaptation-related knowledge in the literature, adaptation actions were categorized for two levels of adaptation; farm-based and policy-driven.

Challenges related to impacts of climate change and the required adaptation actions are of course dependent on biophysical factors other than climate change, such as agro-climatic zone (Iglesias et al., 2012a) and soil type. This review does not structure results based on such preconditions but rather clarifies and synthesises relevant challenges and opportunities depending on various factors related to climate change. Nevertheless, the results of this paper can be used in combination with identified preconditions to determine the relevance of a challenge or opportunity to a specific case.

3. Results

3.1. Opportunities and challenges associated with impacts of climate change

The following sub-sections provide an overview of climate change opportunities (Table 1), challenges (Table 2) and adaptation actions

¹ <http://www.smhi.se/klimat/framtidens-klimat/klimatscenarioer> (accessed: 2017-06-21)

² Search string: ((Agricultur* OR Crop* OR farming) AND Climate AND (risk OR hazard OR stress OR impact OR vulnerability OR effect) AND (adaptation OR action OR response) AND (Nordic OR Scandinavia OR Norway OR Sweden OR Denmark OR Finland))

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