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The increased risk of water scarcity in Scotland due to climate change and the influence of land use on water scarcity: issues and solutions

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Executive summary

This report looks at the future risk of water scarcity in Scotland, and the link between water scarcity and land use options. This work is a useful tool for developing policy for water scarcity implementation in national and regional strategies, water supply systems, and land use priority. Although Scotland is generally considered a wet country, droughts do occur, leading to water scarcity. Droughts will vastly increase in severity and frequency in the next decades due to climate change. This will have major impacts on Scotland's agriculture and citizens. We found that mainly East-Scotland is prone to water scarcity in the summer, and that the expected wetter winters will not be able to make up for the lower precipitation in the summer.

Key findings

- Scotland will experience more frequent and more severe droughts in the coming decades due to climate change. This will influence water availability for drinking water, agriculture and ecosystems.
- As droughts will become more severe and occur more frequently, water supply systems should become more resilient to droughts. This can be done by re-evaluating the balance between the costs for increasing resilience against low water supply episodes, and the probability of their occurrence for all water supply systems. During re-evaluation, the expected low water episodes in the coming decades should be taken into account, as changes in drought risks are happening at a fast rate. This will help the prevention of water shortage during low precipitation episodes. These evaluations need to be performed by SEPA, who will need to collaborate tight with Scottish Water and the Scottish Government to improve the water supply system resilience.
- Scotland's National Water Scarcity Plan helps to manage drought periods both prior to and during these events as the plan improves communication between SEPA, Scottish Water and the Scottish Government.
- Many policies are relevant to managing water availabilities, such as the Land Use Strategy, the Future of Agriculture and the Scottish Forestry Strategy. Implementing water scarcity in these policies would make a substantial improvement to the managing of water availabilities in these policies.
- Land use changes can play a substantial role in decreasing water use. This will help building up resilience against low precipitation events. Effective land use changes include:
- Replacing crops with higher irrigation needs for crops with lower irrigation needs.
- Replacing non-protected crops to protected crops (e.g. in glasshouses or polytunnels) as these are more efficient. Land use change towards protected crops would be more efficient and therefore economically more beneficial than non-protected crops.
- In forestry, tree species with low evapotranspiration rates could be selected.

Content

1 Introduction

Scotland is one of the wetter areas in the UK and in Europe. However, dry summers have occurred several times in the past, resulting in water scarcity. The droughts of 2003, 2012 and 2018 are examples of recent previous episodes. Due to climate change, wetter winters and drier summers are expected in Scotland, leading to a drier East Scotland and a wetter West Scotland (Gosling, 2014 and Brown et al., 2008). This will lead to reduced supply, drier soils and lower river flows during the summer (Brown et al., 2012), especially in vulnerable areas.

Vulnerability is defined as a combination of the adaptability, sensitivity and exposure of areas. Adaptability is the ability for an area to change in order to minimize negative effects. Sensitivity is the amount of change for a given amount of exposure. Exposure is the amount of land use or climate change that takes place) (Sample et al., 2016).

The east of Scotland is drier, more densely populated, and has more agricultural land than the west (Gosling, 2014 and Brown et al., 2008). Therefore, this part of Scotland is considered more vulnerable than the west.

The reduced water supply, drier soils and lower river flows during Scottish summers will affect the land use possibilities in certain areas. This will impact how the land can be used, for example by changing from agricultural land to forestry or vice versa, or a change from water-demanding crops to drought-resistant crops. As agricultural irrigation is required for high-quality produce, and is increasing in many areas (Brown et al., 2012); the need for irrigation should be taken into account when determining the influence of land use on water demand. A changing climate has implications for water supply and demand, but many assessments haven't included land use as an influence on the water supply-demand balance (Brown et al., 2012).

Water resource sustainability is necessary to protect the water supply-demand balance. However, this balance is uneven across Scotland, as the drier areas have much of the demand for water, due to a higher population density and more agricultural land cover.

In summary, Scotland will experience more frequent and more severe droughts in the coming decades due to climate change. This will influence the water availability for drinking water, agriculture and ecosystems. Some water supply systems in Scotland are very vulnerable to low precipitation rates; these episodes will happen more frequently and will become more severe. Therefore, precautionary action is needed to prevent water scarcity to affect Scotland's agriculture, its citizens and its ecosystems.

2 Methods

This report is answering the following set of questions:

1. Is water scarcity an issue in Scotland at the moment or in the future? When and where will it become an issue?

2. How can we best take action on this issue in order to prevent water scarcity to have a negative impact on the Scottish agriculture, population and ecosystems? Which precautionary actions and which policies are already in place and how can they be improved to minimize the negative effect of water scarcity?

3. How do land use decisions impact water scarcity vulnerability?

This report is based on a literature review of topical sources of both academic and non-academic origin. Keywords such as 'water scarcity Scotland', 'water shortage Scotland', 'droughts Scotland', 'land use droughts Scotland', 'water scarcity UK, 'water shortage UK, 'droughts UK, 'land use droughts UK' have been used in the Google and Google Scholar search engine.

3 Results – Water scarcity

A higher interannual variability of precipitation has been predicted in Scotland in the next decades (Brown et al., 2008). This will increase the risk of flooding in the winter, as well as an increase of soil moisture deficit caused by droughts in the summer (Herrera-Pantoja & Hiscock, 2008). Overall, the increased soil moisture deficits will extend into the autumn and will shorten the winter recharge season. The increased winter precipitation will however not be able to compensate for the deficits, as this would require longer periods of steady rain instead of the predicted short periods of intense rain. This will largely influence land quality, which will potentially increase ecosystem and water supply pressures in groundwater-dependent areas. It will also influence the crops that can be grown under these circumstances. Some crops will be considered too risky, despite their potentially higher value (Herrera-Pantoja & Hiscock, 2008), which will influence the potential land use.

Water scarcity is increasing in Scotland. Periods of drought previously only occurring once every 40 years, will happen once every 20 years by 2050 (Gosling, 2014). These increased droughts will require the Scottish water supplies to become more resilient to droughts.

Building up resilience to low water supply episodes is however costly. Therefore, it will be thought-out whether an investment needs to be made to increase the resilience of a water supply system. This decision depends on the vulnerability of a system to droughts, and the chance that a system cannot provide enough water at some point during a drought event (Gosling, 2014). Water supply systems in some parts of Scotland have relatively low levels of storage, and rely on regular supply from precipitation as they rely on small lochs or rivers with little groundwater distribution, especially high altitude systems. These systems are vulnerable locations which are susceptible to droughts. The vulnerability-resilience balance is evaluated by water resource management systems. However, as droughts will vastly increase in both frequency and severity on a short time scale, re-evaluation needs to be done taking these future changes into account. The Scottish Environmental Protection Agency (SEPA) is responsible for these evaluations, and have developed a suite of water shortage indicators which are used to assess the severity of precipitation and river flow anomalies (Gosling, 2014). SEPA could anticipate on a changing future by further implementation of expected future droughts in the models used for these evaluations. This could prevent an increase in frequency of events where water supply systems can no longer supply the necessary amount of water.

A difficulty to detecting changes in water levels, is the time it takes for climate change to become measurable. Because of the high natural variability of the UK climate, climate change in river flows will take some time to be detectable (Gosling, 2014). On top of that, groundwater systems are very susceptible to climate change on a longer time scale, as these systems take a hundred years for the

change to be visible at full extend (Cuthbert et al., 2019). Groundwater has become an increasingly important role for drinking water, with groundwater abstractions by Scottish Water having doubled between 1991 and 2005 (Graham et al., 2009). Currently 140,000 people are dependent on groundwater via private water supplies, and 7% of Scotland's public water supplies are provided by groundwater (MacDonald et al., 2005). Even though groundwater supply will become a large problem on a long timescale, no work has been performed on groundwater resources (Brown et al., 2012).

4 Results – Land use

As mentioned previously, the increased summer droughts in mainly East Scotland, and wetter winters in mainly West Scotland, will have large impacts, as:

- They will result in changes in soil moisture, which will influence the land use possibilities in different regions.
    - The main changes in land use possibilities will be an increase in surface area of best quality land (Crighton & Audsley, 2010).
    - On the other hand, a degradation of land quality of lower quality land will take place (Crighton & Audsley, 2010).
- Increased droughts will affect arable land in different ways:
    - Moisture retentive soils may become more favourable for agriculture,
    - While sandy and gravelly soils may become more disadvantaged (Brown et al., 2008).

Land use options are expected to increase in the east and south of the country, while the most western areas will remain constrained. Even though 85% of Scotland's best quality land is currently being used for arable land (Crighton & Audsley, 2010), the potential in the east and west is not everywhere being actively considered and deliberated (Brown et al., 2008). These areas have economic potential, although care should be taken using these environments for arable land. These areas are often of high environmental importance by their high biodiversity value and their large carbon storage capacity in soils are vulnerable to disturbance (Brown et al., 2008).

Because of the increase in arable high quality land, agricultural expansion is expected to take place, which will involve an increase in the amount of water needed for irrigation. An increase of forests is expected as a means to capture CO_2 as well as to provide a sustainable fuel source. This will result in substantially higher rates of evapotranspiration (a combination of evaporation and transpiration) than other land cover types (Sample et al., 2012). Evapotranspiration of land cover types also influences the demands made upon the water supply network, and therefore different decisions of crops could be made on a sandy or gravelly soil (Sample et al., 2016). The total volume of water required for irrigation may increase by around 30% in 2050 (SEPA, 2015b). Important spatial variations result in hotspots in East Scotland where higher demand for irrigation combines with lower supply from rainfall (SEPA, 2015b). Extrapolation of current crop water demands to the 2050s suggests that water stress could become a severe issue for some areas in East Scotland (Brown et al., 2012). Some areas will become particularly vulnerable, and irrigation demands will increase at some locations with 59% in the 2050s (Brown et al., 2012).

Additional to this increase in irrigation demands, significant reductions in the ability of natural systems to supply water for agricultural irrigation and whisky production are predicted in the 2050s, as well as reductions for drinking water provision and the capacity to dilute waste water and whisky production discharges (Sample et al., 2016). Many areas that experience a reduction in supply also contain high-value crops that are likely to require additional irrigation water.

Land use can thus have a large impact on the water demands in certain areas. Land Use Strategies of 2011-2015 and 2015-2021 have focused among others on the influence of land use on water quality

and flooding risks in Scotland. Regional Land Use Pilots in the strategy of 2011-2015 have focused on the potential expansion of woodlands, and the positive feedback this could have on reducing flood risks and improving water quality. However, a land use strategy depending on water scarcity is missing in these documents, although such a strategy could become essential for the development of a sustainable water supply.

5 Conclusions and recommendations

In conclusion, droughts are currently not very common in Scotland, but will increase vastly in severity and frequency in the next decades due to climate change. The increased droughts will affect all of Scotland, but the most severe droughts are expected in the east of Scotland. These droughts require immediate action to prevent water shortages, among which land use changes. Below, four points of action are set, which will reduce the impact of droughts for Scotland's agriculture, citizens and ecosystems substantially.

Action 1: Increase of water supply system resilience against droughts

Resilience of water supply systems should be increased against low water supply episodes. Currently, the increase of resilience is too costly compared to the low costs of direct summer abstraction. However, this is likely to change as droughts will increase. A more flexible licensing system could help promote effective use of water and improve water conservation, such as encouraging an emphasis on high-value goods or by favouring a shift in production to areas where water is more readily available (Brown et al., 2012).

Action 2: Water scarcity prevention implementation in national and regional strategies

Actions to prevent water scarcity, and actions to take during an event of water scarcity should be implemented in strategies. At the moment, this is not yet the case. For example, water scarcity is neither implemented in the Land Use Strategy 2011-2015 nor in 2016-2021. Also, several documents and strategies, such as The Future of Agriculture – A Discussion Document by The Scottish Government and the Scottish Forestry Strategy by the Forestry Commission Scotland don't mention droughts, but only mention climate change in general. As droughts will have an increasing impact on land use, agriculture, forestry and many more areas, the prevention of water scarcity, and actions to take to minimize the effects of water scarcity are highly recommended to include in these type of documents and strategies.

Action 3: Land use changes

Land use changes are necessary to reduce the gap between water supply and demand in low precipitation events. For example, crops with higher irrigation needs could be replaced for crops with lower irrigation needs. Protected crops (e.g. in glasshouses or polytunnels) are more efficient than non-protected crops (Brown et al., 2012). Land use change towards protected crops would be more efficient and therefore economically more beneficial than non-protected crops. Additionally, in forestry a selection could be made for tree species with low evapotranspiration rates. These measures, in addition to the build-up of resilience in water supply systems, will increase Scotland's resilience to the increasing frequency and severity of low precipitation events.

Action 4: Integration of precautionary actions to Scotland's national water scarcity plan

Scotland's national water scarcity plan is an act that sets out how water resources will be managed during periods of prolonged dry weather (SEPA, 2015a). This plan has set out a number of actions that will be performed to reduce the negative impact of a drought event by communication between the different parties, such as SEPA, Scottish Water and the Scottish Government. However, it does not yet

include precautionary actions to prevent a shortage of water supply in the first place, such as land use change and the build-up of resilience in water supply systems. An integration of these precautionary actions into Scotland's national water scarcity plan could significantly improve Scotland's resilience to the changing climate.

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