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Resource use efficiencies as indicators of ecological sustainability in potato production: A South African case study

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ABSTRACT

Potato, the most important vegetable crop in South Africa, is produced in many distinct geographical regions differing in climate, soils, production seasons and management practices and access to markets. These differences affect the amount of input resources required to produce potatoes as well as yields and crop value, and therefore the use efficiencies of land, water, nutrients, seed and energy. Resource use efficiencies affect the ecological and financial sustainability of potato production in this region, which has in general less favourable potato growing conditions than north-western Europe and the U.S.A., where high resource use efficiencies are usually recorded. This study aimed to assess and benchmark South African potato production regions, representing a wide range of growing conditions, regarding their use of input resources and to identify resource-intensive practices, which may suggest inefficient use of inputs. Surveys were conducted in 2013 and 2014 by interviewing growers in all production regions, to provide data on resource use efficiencies. Quantitative modelling approaches were applied to calculate carbon footprints as a proxy of energy use efficiency, potential crop yields and irrigation needs for each region. Variability in the gap between potential and actual yield was used to identify yield limiting factors. Actual yields achieved were on average 60% of the potential yield, suggesting fairly efficient use of available production factors. Water, seed and nutrient use efficiencies differed widely between and within regions and were not directly proportional to water requirements and yields achieved. Fertilizers (34%) and irrigation (30%) were the greatest contributors to energy use in potato crop production. Energy required to pump water was strongly related to the amount of irrigation applied, pumping depth and distance. Long distance travel of produce to retail points contributed substantially to energy use. Significant improvements in efficiencies are possible by improving management practices. Analysis of the variability in resource use efficiencies between farms and regions provided production sustainability indicators that can assist growers in identifying inefficient practices and yield limiting factors. These can be addressed through the use of decision support systems, such as irrigation scheduling tools, to improve resource use efficiencies and the sustainability of production, not only for the production efficiency of the specific study area, but also for the economic efficiency of potato production anywhere else.

1. Introduction

Potato is the fourth most important food crop in the world (FAOSTAT, 2016). Egypt is the leading producer in Africa in terms of volume of potatoes produced, followed by Algeria, Malawi, South Africa, and Rwanda (FAOSTAT, 2016). Of these countries, South Africa has the smallest production area (about 50 000 ha), but highest average yields (about 43 t ha^{-1}). Potato is produced in 16 geographically and edaphically distinct regions of South Africa (Fig. 1; Table 1). The main growing regions are located in the eastern and western Free State, northern Limpopo and the Sandveld, but sizeable production also occurs in other parts of the country. Commercial potato growers in South Africa are generally skilled and have access to first world crop production and protection technologies. Potato is usually produced under irrigation due to low and unreliable rainfall, with the exception of the eastern Free State where dryland production is dominant. Limited supplementary and full irrigation occurs in this region when irrigation water is

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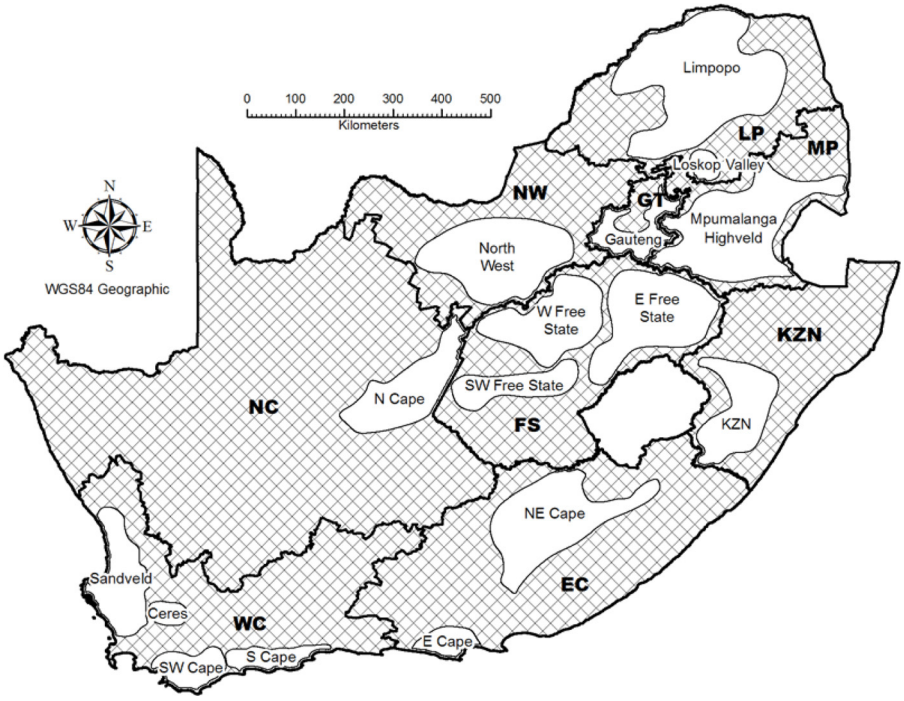

Fig. 1. Map indicating the approximate positions of potato production regions in South Africa. EC = Eastern Cape; FS = Free State; GT = Gauteng; KZN = KwaZulu-Natal; LP = Limpopo; MP = Mpumalanga; NC = Northern Cape; WC = Western Cape; NW = North West (adopted from Van der Waals et al., 2016; designed by L. van Zyl, TerraGIS, South Africa).

available. The availability of irrigation water is limiting in almost all production regions, but especially in regions relying on boreholes as water source (e.g. Limpopo and North West). In most inland regions (except Limpopo) potato production is limited to the summer season due to winter frost. As a result, crops are often exposed to unfavourably high daytime temperatures, which limits productivity. Sandy soils are generally preferred for potatoes, but soils vary substantially between regions. In the Sandveld and Ceres regions the soils are very sandy with low water and nutrient holding capacity, which complicates management. The diversity in growing regions and planting times ensures that fresh potatoes can be supplied to the market all year round (Potatoes South Africa, 2015).

Potato is a high-yielding crop, but its production requires relatively high uses of inputs such as water, seed, crop protection agents energy and fertilizers (Sincik et al., 2008). The amount of inputs needed to produce a given amount of potato, also referred to as the resource use efficiency, affects the ecological and financial sustainability of production. Although potato yields and sales in South Africa have gradually increased over the past decade (Potatoes South Africa, 2015), the potato sector is facing serious concerns about the financial sustainability of production. Costs of most inputs, especially energy (both direct fuel and electricity cost, and the indirect cost of chemicals and fertilizers) have risen dramatically over the past decade (Strydom and van Zyl, 2015). This sharp increase in production costs, combined with a stagnation in product prices is detrimental to the financial sustainability of potato production. For example, in 2015 the average operating input cost per hectare for a target yield of 65 t ha^{-1} in the North West region amounted to 14,030 US$, with gross income of 15,660 US$, resulting in a gross profit of only about 1630 US$ per hectare. It should be clear that if target yields are not achieved, or product prices drop due to over-supply to the markets, the profit can easily turn into a loss (Pieter van Zyl, personal communication). As a result of this harsh economic environment, the number of commercial growers in South Africa has declined by about 50% in the past decade. The international competitiveness of potato industries in developing countries (e.g. in South America and Africa) is also of concern to domestic growers (Haverkort et al., 2014). In South Africa, for example, the processing of raw potato tubers into frozen products is currently only economically viable due to tariff walls protecting the domestic market against cheaper imports from north-western Europe. These tariffs protection measures are unsustainable in the long term.

Climate change is also expected to impact the sustainability of potato production globally. Potato is a heat-sensitive crop and in regions where it is presently being produced under relatively warm conditions, increased heat stress is expected to reduce yields (Haverkort et al., 2013, 2015) and therefore income per unit input. In cooler regions, or where production can be shifted to cooler seasons, however, the positive impacts of increased CO_2 levels on potato yield and water use efficiency may override the negative impacts of increased temperatures (Franke et al., 2013). Furthermore, pest and disease pressure on potato crops is expected to increase as a result of higher temperatures in southern Africa (Van der Waals et al., 2013), and therefore crop protection measures will further add to input costs. Since potato growers have little control over the cost of inputs, the best strategy to improve financial (and ecological) sustainability is to optimise the output (i.e. optimise yield and quality) for maximum income per unit input, i.e. to farm more efficiently (De Koeijer et al., 2003; De Wit, 1992; Nyagaka et al., 2010).

Input resource use efficiencies are often used as indicators of production-ecological sustainability of crop production (De Vries et al., 2010; Van Ittersum and Rabbinge, 1997). Van Asselt et al. (2014), on the other hand, proposed a framework for the evaluation of sustainability of agri-food production systems, which also includes aspects not directly related to production efficiency and sustainability (e.g. food quality and safety, human health, animal and human welfare). Although resource use efficiencies do not cover all aspects of ecological or environmental sustainability, such as biodiversity impacts of land use or animal welfare, they have the advantage of being relatively easy to quantify and facilitate