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Modeling of natural and social capital on farms: Toward useable integration

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ABSTRACT

In a world of increasing population and decreasing availability of arable land, the need to maintain and improve the quality of our farm systems is a clear and pressing one. Considerations of different types of capital give us a more holistic picture of what is at stake. Our decision-making mechanisms and tools must seek to integrate all types of capital, including natural and social capital, if we are to sustain long-term farm performance. Modeling is one way to integrate this 'expanded' notion of capital. While farm modeling is not a new concept, this paper reviews various types of models with the aims of determining which is most suitable to demonstrate the effect of natural and social capital on farm risk, farm resilience, and farm well-being. As an industry particularly vulnerable to extreme weather patterns and other ecological hazards, the concepts of risk and resilience are critical to sustain long-term farm well-being. Various types of farm models are covered in this review, including land use cover and change, agent-based, statistical, system dynamics, and participatory modeling. The paper also identifies key characteristics that assist in modeling the effects of natural and social capital management. I conclude that an integrated, spatially explicit, participatory, systems-based modeling process is suggested to usefully incorporate natural and social capital effects on farm risk, resilience, and well-being. This approach can incorporate a whole systems approach, capture system 'leverage points', and effectively involve affected stakeholders.
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1. Introduction

In a world of increasing population and decreasing availability of arable land, the need to preserve, maintain, and improve the quality of our agricultural systems is a clear and pressing one as agriculture has always been vulnerable to extreme weather patterns and other ecological hazards (Berry et al., 2011). As such, risk and resilience are constant factors in the management of these socio-ecological farm systems (Fraser et al., 2011). With the pressures of climate change, these threats are more likely to increase in frequency and intensity, which in turn threatens both sustainable food production and the well-being of farmers (IPCC, 2014; Berry et al., 2011). This growing risk affects farmers and consumers, as well as the financial and policy institutions supporting these systems, presenting an incentive for the joint development of a tool that measures, analyzes, and predicts this risk (OECD, 2009). Such a tool would allow for better, and more informed, farm management, reduced risk, increased resilience, and better long-term well-being. Models can provide that tool, but should go beyond a solely economic examination of the economic aspects of risk. Well-being consists of more than a person's level of income or economic productivity; there are social and environmental influences on individual and societal well-being (Costanza and Daly, 1992; Daly and Farley, 2011). As such, considerations of natural and social capital must be integrated into any model to be successful and valuable in considering risk, resilience, and well-being.

In this review, I examine various types of models used to simulate farm scenarios while identifying key characteristics of those models that would be helpful in simulating the effects of natural capital and social capital management on farms. Best practices of modeling and key elements of the models reviewed form the basis for suggesting that a spatially explicit, participatory, systems-based modeling process may provide the best option for illustrating the relationship of natural and social capital with farm risk, resilience, and well-being. This approach offers a holistic consideration of a farm system, can capture system leverage points, and will involve affected stakeholders, regardless of the size, type, industry and location of the farm(s) being modeled.

2. Background

Farmers, financial institutions, and government agencies all have an inherent interest in understanding the nature of the contributions of natural and social capital towards risk, resilience, and well-being. Already, there are a number of studies (Challinor et al., 2009; Howden et al., 2007; Rodriguez et al., 2014) that argue "farmers who invest in their natural capital assets (including soil health) reap benefits including improved profitability and/or increased business resilience (more consistent yields and profits over time)" (NAB, 2014). But this recognition is not yet widespread, and there are few studies that equally consider the role of social capital in a farm's risk, resilience, and long-term well-being (Smit and Skinner, 2002; Pretty and Ward, 2001; Pretty, 2003; Adger, 2010; Getz, 2008).

Where the interests of financial institutions and government agencies lie is in the protection of their considerable investments in the agricultural industry, the practice of land management and into farms themselves. To make informed decisions, financial institutions and government need tools to understand, measure, and predict the influences of environmental and social impacts on their investments. This has become an issue of increasing importance, as demonstrated by recent global agreements that emphasize an expanded consideration of capital. For example, the Natural Capital Declaration, a partnership between global financial institutions and the United Nations Environment Programme (UNEP) seeks "to integrate natural capital considerations into loans, equity, fixed income and insurance products, as well as in accounting, disclosure and reporting frameworks" (UNEP FI & GCP 2013). However, the Natural Capital Declaration does not integrate considerations of social capital (Adger, 2010; Cantor and Rayner, 1994; Platteau, 1994, 2000).

Lewis and Conaty (2012) list social capital and 'ecosystem services' (derived from natural capital) as two of seven key characteristics of building societal resilience. Social capital and natural capital might not be the only factors in such a transformation and even when fully integrated, they may not be able to completely eliminate the risks of natural hazards or the problems of social disconnection that can be found in farming communities (Berry et al., 2011). However, a more complete integration of natural and social capital into farm management is the first step to fundamentally transform conversations around risk, resilience, and well-being on farms.

2.1. Capital and well-being

Drawing from the field of ecological economics, expanded forms of capital seek to integrate considerations of oft-neglected 'externalities', of both an environmental and social nature, into our economy (Costanza and Daly, 1992). By internalizing these costs, 'true' prices can be considered, thus allowing consumers and the market to make decisions based on the full economic, environmental, and social costs of goods and services (Costanza et al., 1991).

For this paper, the four main types of capital are as follows: built, human, natural, and social. Built capital is the built environment of humans, consisting of "buildings, machinery, transportation infrastructure, and all other human artifacts and services that fulfill basic human needs such as shelter, subsistence, mobility, and communications" (Costanza et al., 2013, Boumans et al., 2002).

Human capital is the capacity of humans (physical, mental, knowledge, etc.) that enables them to contribute to human society and facilitate the creation of personal, social, and economic well-being (Costanza et al., 2013, p. 22; Brian 2007; Boumans et al., 2002). This human capital involves investment in oneself or others to find a job, improve their education, stay healthy, find spiritual fulfillment, create art, etc. (Costanza et al., 2013, p. 22; Brian 2007).

Natural capital is the natural environment and the biodiversity contained within that is necessary for the provision of the ecosystem goods and services "essential to basic human needs such as survival, climate regulation, habitat for other species, water supply, food, fiber, fuel, recreation, cultural amenities, and the raw materials required for all economic production" (Costanza et al., 2013, p. x).

Finally, social capital consists of the "networks together with shared norms, values, and understandings that facilitate cooperation within or among groups" (Brian 2007). Social capital is often divided into three types of connections: bonds, links to people based on sense of common identity; bridges, connections that stretch beyond shared identity; and linkages, our networks that vertically tie to people up or down the social ladder (Brian 2007; Pretty 2003). These connections can contribute to social cohesion, stronger communities, good governance, and creating a sense of affection and belonging through participation (Pretty, 2003; Adger, 2010; Katz, 2000).

Increasingly, the academic literature has found that these various types of capital interact to contribute to human well-being and suggests that human welfare is not solely the product of income or productivity, as neoliberal economics might suggest (Costanza and Daly, 1992; Daly and Farley, 2011; Adger, 2010; Vemuri and Costanza, 2006; Costanza et al., 2014b). One such example is the positive correlation between social capital and improved mental health; this has particular relevance for farmers, who benefit from

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