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ANALYSIS

Non-separability and heterogeneity in integrated agronomic–economic analysis of nonpoint-source pollution

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Abstract

This paper highlights two aspects that are crucial in the management of agricultural nonpoint-source pollution, but that are typically not taken into account in applied economic studies. Firstly, production, pollution and abatement are to be treated as *non-separable* to include control options provided by changes in production practices. Besides, non-separability enables proper account to be taken of the material flow through production processes and changes the perspective on optimal environmental regulations. Secondly, the resolution or level of spatio-temporal aggregation should capture the *heterogeneity* in the economic and ecological attributes (production condition, fixed but allocatable inputs and technology set) of the individual decision-maker's policies they intend to influence. The implications of non-separability and heterogeneity for empirical studies and for policy are illustrated by two simulation studies on nitrogen and pesticide use in crop farming.

Keywords: Non-separability; Heterogeneity; Pesticides; Nitrogen surplus; Simulation models; Interdisciplinary analysis; Crop farming

1. Introduction

The analysis of agro-ecosystem sustainability requires establishing communication between bio-physical and socio-economic disciplines. Interdisciplinary research on sustainability requires identification of the proper spatio-temporal scales to be covered in the analyses, effective communication of concepts, consistent organization of data, translations of concepts and data into integrative models and a structured presentation of model results (Weston and Ruth, 1997). For non-point-source pollution these requirements are extensively discussed in the theoretical literature (e.g. Antle and Just, 1992; Russell and Shogren, 1993), but frequently not met in applied work. For example, Vatn et al. (1997, p. 208) review

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examples of policy relevant studies for nonpoint-source pollution from agriculture and conclude that in-depth integration of the various disciplines involved is in fact still very rare.[1] More recent publications do not show much improvement in this respect as their main concern is not with further conceptual integration, but particularly with the use of geographic information systems (GIS) to organize data and present results (e.g. Skop and Schou, 1999).

The purpose of this paper is to highlight two aspects that are critical in particular in the integrated analysis of control of agricultural non-point-source pollution, but that are typically not both[2] taken into account in policy relevant work. Firstly, production, pollution and abatement are often treated as *separable*, which excludes control options provided by changes in production practices and input substitution. Separability also precludes proper account being taken of the material flow through production processes and leads to an unnecessary emphasis on emissions in policy analysis and recommendations. Secondly, for policy analysis it is crucial for the resolution or level of spatio-temporal aggregation to capture the *heterogeneity* in key economic and ecological attributes of the individual decision-maker's policy intends to influence. Farmers are the agents that decide on production practices, also for the larger ecological or administrative systems for which policy objectives are usually formulated, such as watersheds, aquifers and counties or states.

We proceed as follows. Section 2 provides a theoretical discussion of non-separability of production and abatement in the static, non-spatial setting. Section 3 and Section 4 discuss heterogeneity due to variation in productive capacity (resource base, crop and equipment) both in the static and dynamic setting, and Section 5 focuses on scaling up. Section 6 provides two case studies to demonstrate integrated modeling in the econometric setting and the activity analysis/programming setting, respectively. The paper concludes with a discussion and priorities for further research.

2. The static, non-spatial economic model of agriculture–environment interactions

Whereas economists take the biophysical input–output relationships embodied in the production function as given, this is the central topic in agronomy. Agronomy is the interdisciplinary science that integrates the knowledge of basic physical, chemical, physiological and ecological processes in agro-ecosystems and uses that to understand, devise and manipulate their functioning. The functioning of an agro-ecosystem is determined by the abiotic and biotic natural conditions, by the inherent characteristics of the crop and by the control of abiotic and biotic conditions by management practices. Based on the knowledge of the underlying crop growth and production techniques, optimal combinations of inputs are identified to realize a particular — not necessarily maximum — output level (Baeumer, 1992).

Economic specifications for incorporating the agriculture–environment interactions should have the capability of integrating the biological and physical processes in a manner consistent with agronomic insights. Production externalities (viz. pollution or resistance) most often result from specific inputs that have the characteristics of joint inputs, as any quantity simultaneously pro-

[1] Besides the ECECMOD system by Vatn et al. (1997), the two main examples are the NELUP system (O'Callaghan, 1995) and the CEEPES system (Bouzaher et al., 1995). These models are based on land class (NELUP), hydrological region (CEEPES) and farm information (ECECMOD), respectively. Integrated studies of agricultural activities of individual farms connected with ecological models are more common (e.g. Moxey and White, 1994; Oglethorpe and Sanderson, 1999) but far less insightful for policy analysis/design due to the low level of aggregation. Policy analysis requires analysis at the regional, national or higher level. ECECMOD and NELUP have thus far only been applied for much smaller areas. CEEPES has been used for the continental U.S. but covers heterogeneity rather superficially.

[2] Models of agriculture activities at the farm-level connected with ecological models do account for non-separability but not for heterogeneity, whereas large scale ecological-econometric models generally do not account for non-separability. An exception is CEEPES (Bouzaher et al., 1995), which is a large scale model that does include separability but not farm heterogeneity.