DOI: 10.2478/v10051-012-0016-2

System Dynamics Model for Policy Scenarios of Organic Farming Development

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This paper presents the system dynamics model of organic farming development in order to support decision making. The model seeks answers to strategic questions related to the level of organically utilized area, levels of production and crop selection in a long-term dynamic context. The model will be used for simulation of different policy scenarios for organic farming and their impact on economic and environmental parameters of organic production at an aggregate level. Using the model, several policy scenarios were performed.

Key words: organic farming; system dynamics; simulation; model

1 Introduction

Organic agriculture system dynamics (SD) methodology (Forrester, 1958) can be used as an alternative to the econometric and mathematical programming approaches (Bockermann et al., 2005; Elshorbagy et al., 2005; Saysel et al., 2002; Škraba et al., 2003) for policy modeling. Recently, there have been many important SD applications in the field of agriculture and environment: Nalil (1992) describes the conceptual development of FOSSIL2, an integrated model of U.S. energy supply and demand, which is used to prepare projections for energy policy analysis in the U.S. Department of Energy's Office of Policy, Planning, and Analysis. Munitič and Trosić, (1997) used system dynamics for the modeling of the ecological subsystem of "Kastela Bay". Guo et al. (2001) presented an environmental system dynamics model named ErhaiSD and developed for supporting an environmental planning task. The ErhaiSD consists of dynamic simulation models that explicitly consider the information feedback that governs interactions within the ecosystem. Such models are capable of synthesizing component-level knowledge into a system behavior simulation at an integrated level. Fischer et al. (2003) utilized the power of three-dimensional visualization to present simulation results from a system dynamics model of global protein consumption. A similar approach has been presented by Weber et al. (1996). Shen et al. (2009) presented a system dynamicsmodel for sustainable land use and urban development in Hong Kong. The model is used to test the outcomes of different development policy scenarios and to make forecasts. It consists of five sub-systems including population, economy, housing, transport and urban/developed land. Yin and Struik (2009) reviewed recent findings on modeling genotypes and environmental interactions at a crop level, moving from system dynamics to system biology. However, the most important works in the field of simulation of development policy scenarios are presented by Shi and Gill (2005), who developed a system dynamics-based simulation model for ecological agriculture development for Jinshan County (China), and by Kljajić et al. (2000, 2002, 2003), who developed an integrated system dynamics model for development in the Canary Islands, where interactions between agriculture, population, industry and ecology were taken into consideration. The preliminary investigations into SD simulation of organic farming development have been conducted by Rozman et al. (2007) and by Škraba et al. (2008). In this model, the overall demand and production has been considered, which is important on the national level and represents certain limitations for expansive development of organic farming.

This paper describes a further improvement of the previous model and presents a system dynamics model for the development of organic agriculture in Slovenia in order to identify key variables that determine conversion dynamics and

Received: 11th January 2012; revised 4th March 2012; accepted 3rd July 2012

to propose development policy in order to achieve strategic goals as set in the Action plan ANEK. First, we present the main flows and feedback loops within the systems and the development of the system dynamics model. The results section presents scenarios (different policies in organic farming) and their evaluation through application of the developed SD model. The main findings and suggestions for further study conclude the article.

2 Methods

The simulation model should consider the key variables that influence the development of organic farming, such as:

- the number of conventional farms,
- the number of organic farms,
- conversion process,
- subsidies,
- the promotion of organic farming (marketing, market development, education),
- the organization of a general organic farming support environment,
- a system of self-awareness, and
- the delay constants of process change.

A key variable in the model is the number of organic farms. These are the farms that are under the control system of one of the control organizations. The growth in the number of organic farms was initially (in year 1998) almost linear; however, in the years from 2003-2005, the growth moderated to approximately 4%, despite an increase in subsidies of 20-30%.

During the development of the CLD diagram (Figure 1) as the first step toward the development of the SD model, the following key variables were identified:

1. the number of potential candidates (farms) for conversion to organic farming,
2. the number of farms already converted to organic farming, and
3. the flow between (1) and (2): conversion rate (transition).

Loop B1 represents a negative loop, with a goal value of 0 (depleting the number of “Conventional Farms”). The number of “Conventional Farms” divided by the “Total Number of Farms” yields the “Concentration of Conventional Farms”, which is initially high, meaning that there should be a high initial preference for “Conversion”. “Concentration of Conventional Farms” positively influences the “Communication”. This variable represents the general communication between the conventional approach members and the organic approach

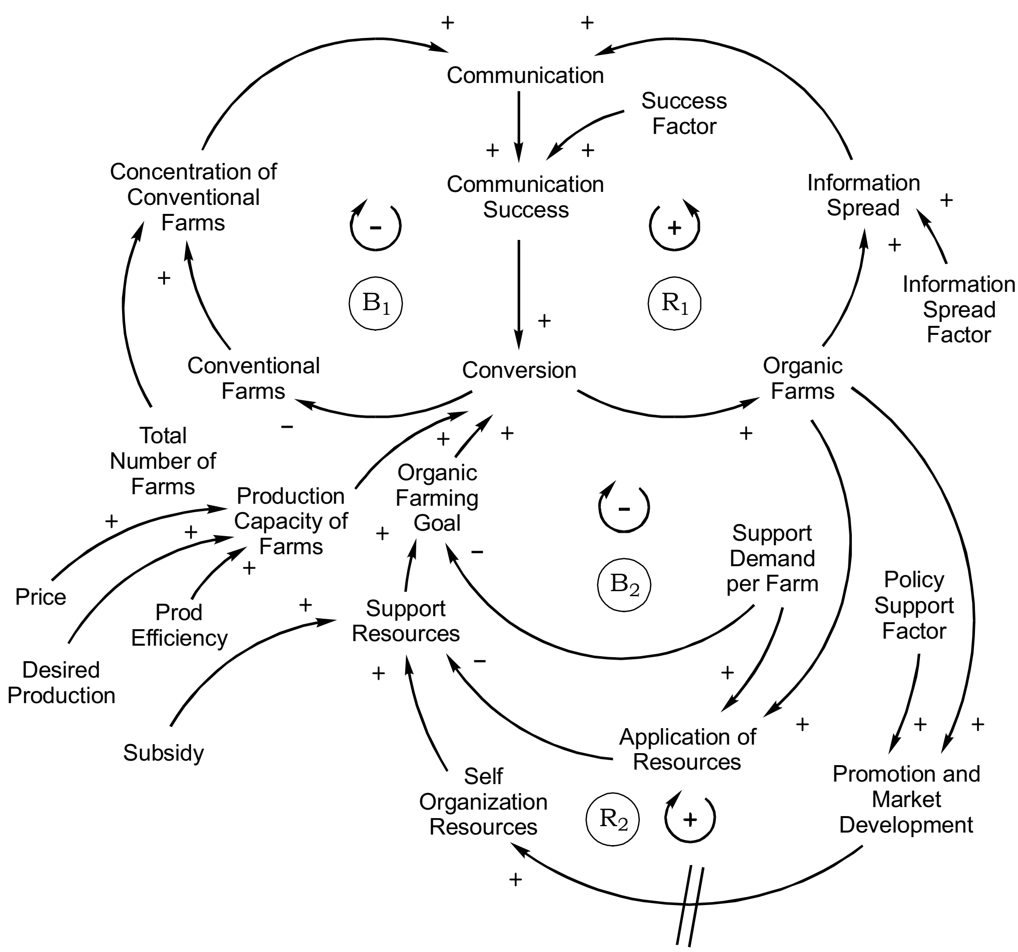

Figure 1: Causal Loop Diagram (CLD) of conversion process to organic farming

members. “Conversion” positively influences the number of “Organic Farms”. If the number of “Organic Farms” increases, the “Information Spread” increases above the level that it would otherwise have been. “Information Spread” by “Organic Farms” members is positively influenced by the “Information Spread Factor” which could be, for example, increased by marketing campaigns. “Information Spread” positively influences “Communication”. The number of “Conversion” farms is determined by the “Success Factor”, which determines the “Communication Success”, yielding the number of convinced conventional members that decide to make a “Conversion”. Loop R1 is a reinforcing feedback loop compensated for by the initial balancing feedback loop marked with B1. If the number of “Organic Farms” increases, the “Promotion and Market Development”, supported by the “Policy Support Factor”, increases as well. Higher “Promotion and Market Development” positively influences the “Self Organization Resources”, which contribute positively to the “Support Resources” on which the “Conversion” is dependent.

There is a delay mark between the “Promotion and Market Development” and “Self Organization Resources”. Longer delays should be expected here since a significant amount of time is needed in order to promote both the organic farming idea and the marketing channels that will support organic farming.

The “Support Resources” are significantly dependent on the government “Subsidy”. Furthermore, the higher the “Organic Farming Goal” is set, the more “Support Resources” are available, meaning that a larger number of organic farms can be supported. If the “Organic Farming Goal” increases, the “Conversion” increases above the level that it would otherwise have been.

The interconnections marked with “R2” have the characteristic of reinforcing feedback loop. According to government policy, the growth in the number of “Organic Farms” should be properly supported in order to promote an increase in self-organization of, for example, organic food marketing and pro-

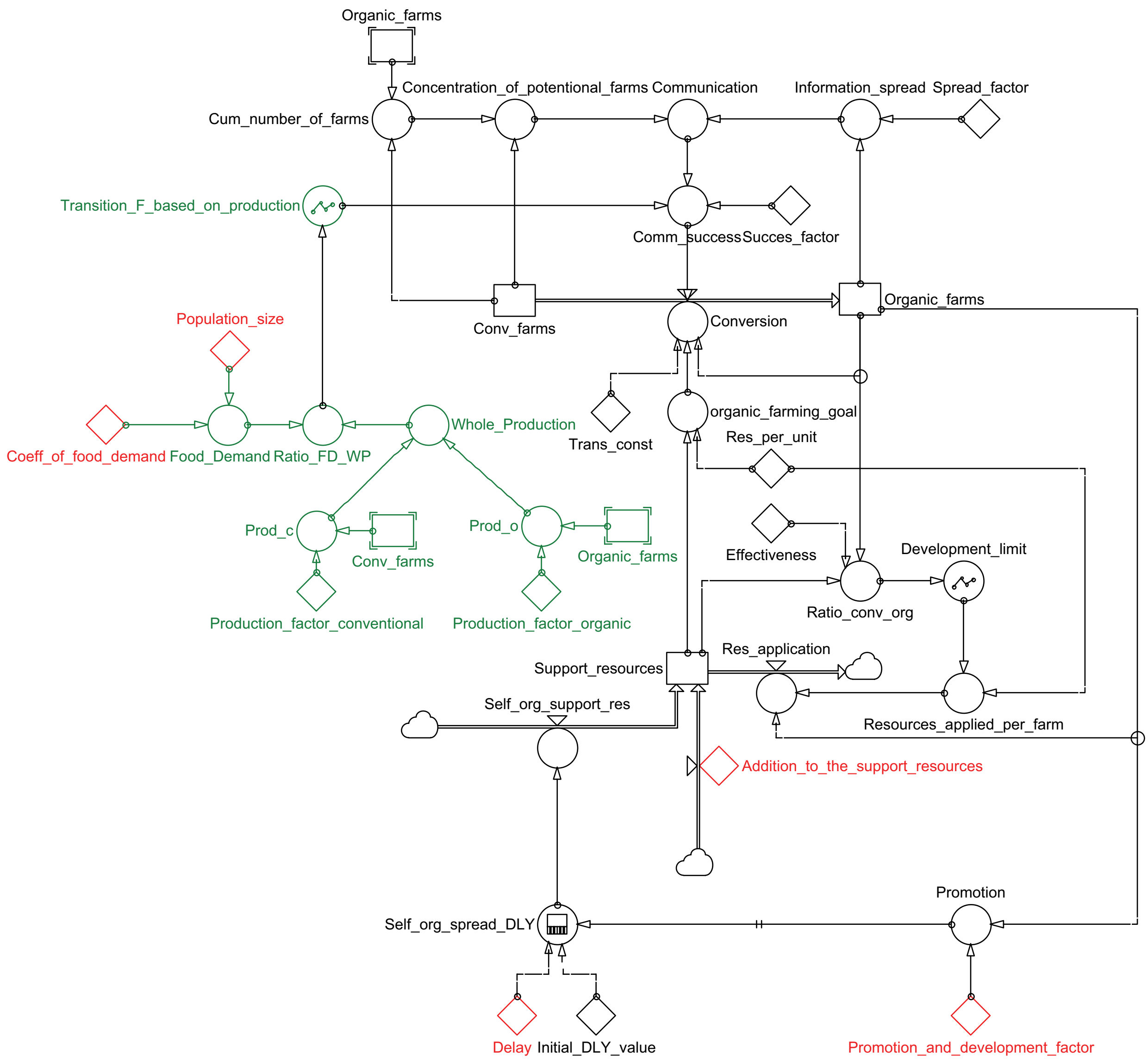

Figure 2: System dynamics model of organic farming development

motion. Thus, the reinforcing feedback loop R2 should serve as a growth generator in the system.

Loop B2 represents a balancing loop. If the number of “Organic Farms” increases, the “Application of Resources” increases above the level that it would otherwise have been. The “Application of Resources” is also dependent on the resources needed per farm, i.e. “Support Demand per Farm”. Higher “Application of Resources” can cause the depletion of the “Support Resources”. The “Organic Farming Goal” is dependent on the “Support Demand per Farm”. If more resources are needed per farm, fewer organic farms can be supported, and therefore lower numbers of “Conversion” should be expected. In considering a real case, the negative loops R1 and R2 are dominant, leaving the system in an undesirable state of equilibrium. This would mean that the number of organic farms is constant and well below that desired. In order to move the system away from the equilibrium, one should consider the policies that would raise the impact of the reinforcing feedback loops B1 and B2, which should move the system state, i.e. the number of “Organic Farms”, to the higher equilibrium values. “Price”, “Desired Production” and “Production Efficiency” are also important factors which impact the intensity of the transition.

A system dynamics model structure is shown in Figure 2. The model consists of 36 variables and 60 links.

There are two levels to the elements applied in the upper part of the model: The variable “Conventional_farms” represents the number of conventional farms. By the flow “Conversion”, the “Conventional_farms” become “Organic_farms”.

This structure is commonly known as the market absorption model. “Conversion” is dependent on the “Organic_farming_goal”. The goal is set by the “Support_resources” available, modeled as a level element. The desired conversion can be achieved only if there are enough “Support_resources” present in order to make a “Conversion”. The “Support_resoures” are not only the financial means. Here, the support of the society is also considered; for example, education should create positive attitudes in relation to organic farming. In this category, the market development, as well as the demand, should also be considered. However, at present, the “Support_resources” are mainly dependent on subsidies from the government. The important variable “Self_organization_resources” is driven by the impact of the policy and the level of societal support, which will intensify with increasing numbers of “Organic_farms”. This represents the application of a reinforcing feedback loop

Table 1: Input parameters for each scenario

Scenario	Subsidies	Coefficient of food demand	Delay	Promotion factor	Population
1	2000	1,2	24	0,8	2M
2	3000	1,2	24	0,8	2M
3	4000	1,2	24	0,8	2M
4	4000	1,2	24	2	2M
5	4000	1,2	48	2	2M
6	4000	1,2	48	2	2.3M
7	4000	1,1	48	2	2.3M

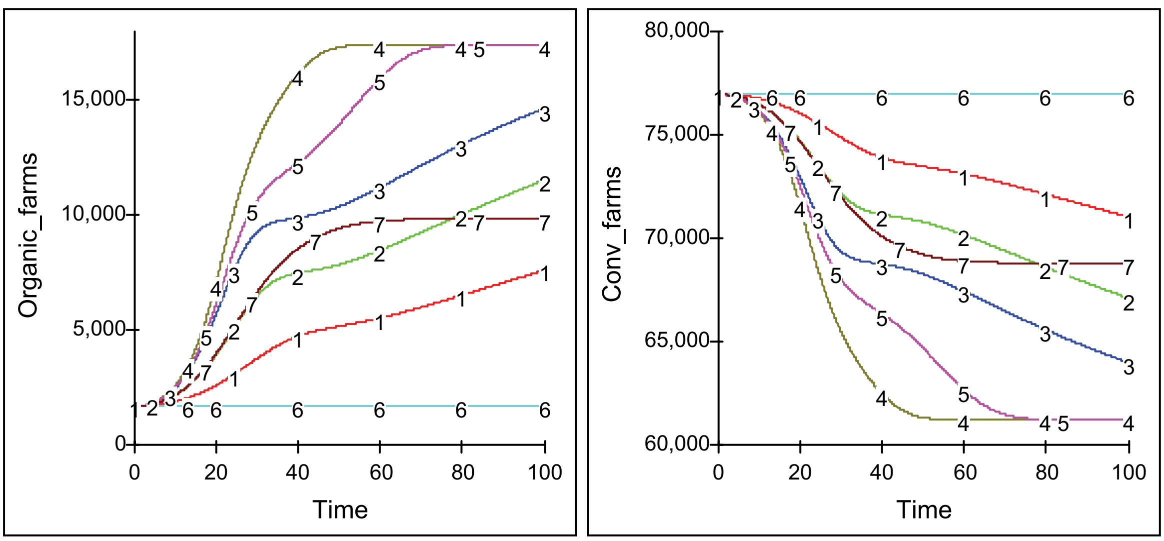

Figure 3: Number of organic farms

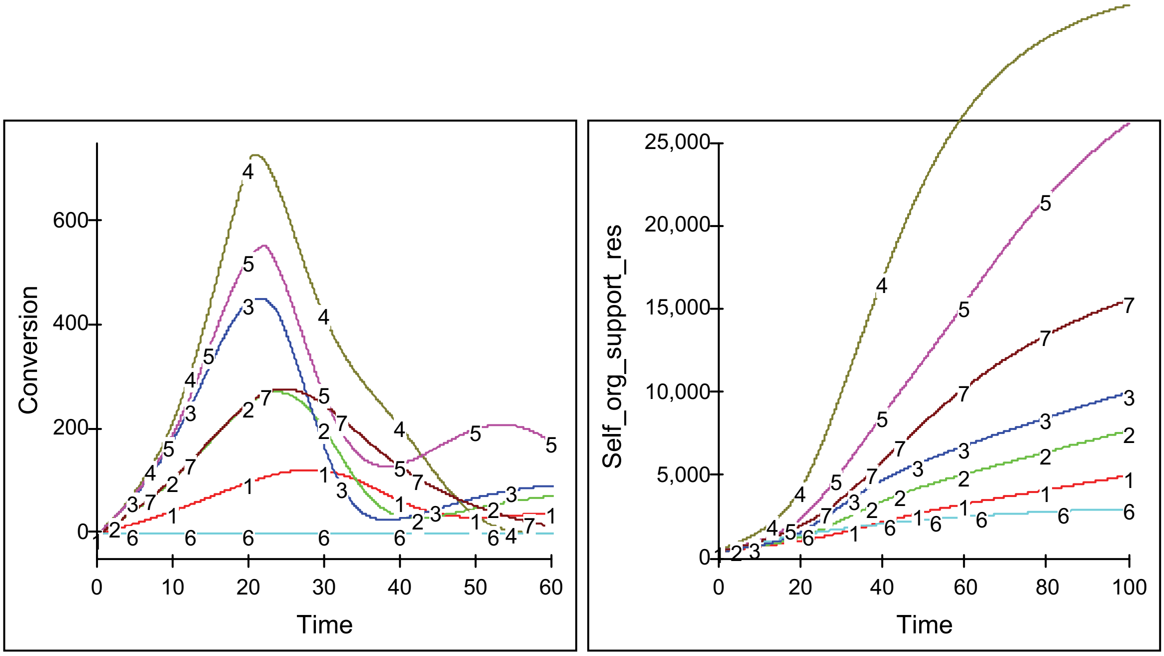

Figure 4: Conversion dynamics

which should be augmented. The “Development_limit” represents the function which considers the variable consumption of the resources. If the resources are scarce, the usage is lower than in the case of abundance. Resources are consumed by the “Organic_farms”. The prosperity of the “Organic farms” therefore depends on the “Support_resources”, which are not only financial means. Here, the social impact of organic farming represents the supportive environment which should sustain such an activity, which in the world of consumption is counterintuitive. The “Conversion” is also dependent on the total food production and “Food demand”.

3 Results and discussion

The model is used in order to simulate different scenarios that enable the assessment of policy scenarios with respect to the development of organic farming. Table 1 shows input parameters for 7 scenarios simulated. The main policy parameter being changed is the “subsidies” category.

Scenarios 1, 2 and 3 (Figures 3 and 4) represent the increase of the subsidies and the impact on the transition rate. Scenario 4 shows the impact of the increased promotion factor, which would yield the higher limit conversion to the organic farming. The impact of the increased delay in providing self-support resources is shown by Scenario 5. Here, one assumes that this delay is increased from two to four years on average. Scenario 6 represents the increase in the population which would lead to the status quo in the number of Organic and Conventional farms. It is supposed that the transition in this case would not occur due to the increased food demand. In this case, the negative conversion could also be considered; however, this is the limitation of the proposed model. Scenario 7 shows the transition to organic farming if the coefficient of food demand decreased, which would be the case if, for example, the imports of food increased.

However, the system dynamics model does not provide numerical forecasts. It is rather a policy tool that examines the behavior of key variables (number of organic farms) over time. Historical data and performance goals provide baselines for determining whether a particular policy generates the behavior of key variables that is better or worse when compared to the baseline or other policies. Furthermore, models provide an explanation for why specific outcomes are achieved. Simulation allows us to compress time so that many different policies can be tested, the outcomes explained, and the causes that generate a specific outcome can be examined by knowledgeable people working in the system before policies are actually implemented.

4 Conclusion

After performing several simulation scenarios, the following findings could be abstracted:

- Conversion to organic farming relies on subsidies which provide the main source of conversion from conventional farming to organic farming.
- Subsidies are not the only driving force in the system; even more important are other activities that promote organic farming.
- Subsidies could not be provided in sufficient amounts in order to complete conversion from conventional to organic farming.
- A feasible strategy to achieve complete conversion should consider reinforcing the feedback loop between resources, number of organic farms and supportive actions which are bounded to the number of organic farms.

- The current output parameter, i.e. number of organic farms, is caught in an unwanted equilibrium value due to the domination of balancing feedback loops in the system.
- The important factor is self-organization of the organic farming environment, which includes market development and general public awareness.

Further strategic actions should consider the dynamic response of the system and the feasibility of the stated system target values. Consideration should be paid to the interaction between the four main feedback loops indicated in the system which determine the system performance and provide the means for proper definition of control strategy. The main advantage of the SD model is its capability to assess policy changes and the response of target variables over time. Such models should be useful tools for policymakers to use in planning strategies for the sustainable development of organic farming. Furthermore, it could be extended to other fields closely related to supplemental activities on organic farms, such as farm tourism.

5 Acknowledgement

This work was supported partly by Slovenian Research Agency ARRS Program Grant »Sistemi odločanja v elektronskem poslovanju« No. UNI-MB-0586-P5-0018 and partly by the project CRP V7-1118 Economics of organic farming in Slovenia.

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