SEGAE: a serious game project for agroecology learning

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Abstract: *The main challenge of European agriculture is to provide food in sufficient quantity and quality while reducing its pressure on the environment. Agroecology seems a very relevant option to meet this challenge. The agroecological transition requires farmers, farm advisors and other agricultural professionals to have a holistic understanding of farming systems and agricultural practices, but most courses on agricultural science remain organized by discipline. There is thus an urgent need to develop more multidisciplinary and innovative approaches for agroecology teaching. This article presents a European project whose purpose is to develop an online serious game on agroecology. The main characteristics of the game are presented, as well as its intended uses. This serious game, as well as the other pedagogical resources produced during the project, is hoped to provide some useful material for a more multidisciplinary and experiential learning of agroecology in European Universities.*

Keywords: *serious game, agroecology, systems thinking, active learning, transdisciplinarity, integrated crop livestock system*

Introduction

European agriculture is facing many challenges, among which producing food and non-food products in sufficient quantity and quality, providing employment and profit for farmers and food chain actors, while reducing agricultural impacts on the environment (Garnett et al., 2013; Ponisio & Kremen, 2016).

Agroecology can be defined as “the study of the interactions between plants, animals, humans and the environment within agricultural systems” (Dalgaard et al., 2003). Agroecological practices aim at increasing the level of ecosystem services provided to farming systems in order to sustain production while reducing environmental impacts through the decrease of anthropogenic inputs (Bommarco et al., 2013). Agroecology is thus seen by several authors as a very pertinent option to reconcile the social, economic and environmental dimensions of agricultural sustainability (Godfray et al., 2010; Gliessman, 2014). This is in line with a growing number of local, national and international regulations encouraging an agroecological transition of agriculture (support to investment, access to advice...), in order to decrease its negative environmental impacts while enhancing the ecosystem services it provides. It is thus necessary to build awareness and introduce the concepts of agroecology in the curricula of current and future professionals in the field of agriculture, i.e. students, future farmers and counsellors, as well as active professionals (Valley et al., 2017).

However, higher education in most EU Universities is not yet fully adapted to train the future agricultural professionals on this topic. In particular, multidisciplinary approaches are not very developed in existing programs (Francis et al., 2008). In their professional life, students will be facing agricultural challenges that can only be solved with a holistic view of farm management, encompassing animal and veterinary sciences, agronomy, ecology, environmental, economic and social sciences. The traditional, mostly discipline-oriented learning methods applied at university have often failed to help students understand the complex relationships between farming practices, agricultural production, environmental impacts and economic results.

Moreover, current pedagogical methods often lack interactive and experiential dimensions (Lieblein et al., 2004; Schroeder-Moreno, 2010). Theories on learning suggest that it is more effective when it is active, experiential, situated, problem-based and provides immediate feedback (Kiily, 2005). Only 20 % of oral information is usually memorized, whereas one understands and remembers 90 % of the information when experimented (Davis and Summers, 2015). Serious games appear to offer activities that exhibit these features. They offer an alternative pedagogy based on action and emotion. The learner is immersed in a virtual environment, where he can experiment different things, with no fear of doing mistakes. Then, reflecting on his actions, he will integrate good attitudes and new competences. Pieces of knowledge are disseminated throughout - or aside of - the game in the form of digital resources. It is an original and motivating learning experience adapted to the new generation of learners. Moreover, differentiated instruction can be implemented: different learning objectives can be set up to adapt to the different levels of knowledge of learners. This can explain why game-based learning has been rapidly growing in recent years (Qian and Clark, 2016).

However, few serious games are related to agriculture, and fewer address agroecological issues with a systemic view. Due to the strong incentives towards agroecology in Europe and the attractiveness of active learning tools, we think that a serious game on agroecology can be a very useful pedagogical tool.

This paper presents an Erasmus+ project aimed at developing a serious game for digital learning of agroecology. The project is called SEGAE, which stands for Serious Game in AgroEcology. It is developed by six European Universities from Belgium, France, Italy and Poland. The main features of the game are presented, and some interesting features from existing serious games are identified to be reused in the game. Finally, limitations of serious games in general and this one in particular are identified.

Objectives of the SEGAE project

Targeted public

The serious game is mainly aimed at higher education students. Due to the consequent level of knowledge required to play the game, BSc students in the fields of agroecology, plant and animal sciences and MSc students from other fields related to agriculture (environmental sciences, economics, sociology) are our priority targets. However, the game will also be available for agricultural high schools with adapted pedagogical scenarios. The pedagogical activities proposed with the game will vary depending on the public. However, these should include (i) a presentation of the learning objectives and an overview of the game, (ii) a game play with the adapted scenario, and (iii) a discussion of results, methodology and the limitations of the game with the teacher.

Our contacts with agricultural co-operatives have also helped us identify a potential interest of agricultural counsellors for a better systemic vision of agriculture and information about agroecological practices. The game might in this case be part of a training on systems thinking or agroecology.

Targeting both students and current professionals will increase the number of users and potentially accelerate the diffusion of holistic agroecological thinking. It will however require developing pedagogical scenarios that are adapted to the learning needs and prior knowledge of those two different publics.

Main learning objectives

Our project plans to develop a serious game responding to three main objectives:

1. Help the players acquiring a systems thinking methodology, which is an essential skill for complex problem solving in agroecology (Francis et al., 2011; Debruyne et al., 2017). The players can learn this methodology by analyzing the farming system with indicators providing information on its technical features as well as systemic economic, environmental and social sustainability indicators. The game combines several scientific fields (plant science, animal and veterinary science, soil science, ecology, economics and social sciences) in a model whose properties cannot be anticipated by analyzing any one part of the system in isolation.
2. Find adapted solutions to solve a given agroecological problem. Putting the players in a situation of active learning and experimentation will allow them to test various options that a farmer could choose, and to instantly see their consequences on multiple aspects of the farm management. This inductive pedagogical approach helps the players evaluate the implemented actions, adapt their actions to their goals, and most importantly (Francis et al., 2011).
3. Provide practical knowledge about a large diversity of agroecological practices, their effects in different contexts and how to combine them in order to increase farming systems sustainability. This practical knowledge is also identified by De Bruyne et al. (2017) as a critical skill for agroecology learning, and the serious game provides a tool to improve learning by “doing in silico”.

Intended pedagogical activities

Several pedagogical uses will be possible with this game:

- *"Systems thinking"*: the player will start with a typical farm from a chosen partner country (Belgium, France, Italy or Poland), and will have to improve as much as possible its economic, environmental and social results in a given virtual time (for instance 10 years). Various agroecological practices will be available, given an annual budget and working time. A set of steering indicators will help the player assessing the global impacts of his choices. This first game mode will enhance the player’s comprehension of farming systems in their specific socio-ecological context.

- *"Agroecological practices"*: the game will provide a large choice of agroecological practices. Detailed information will be available for each of these practices. The player will be able to get some scientific information on each practice, and to test its effects on the farming system. This game mode will provide scientific knowledge on agroecological practices and their systemic effects.

- *"Teacher mode"*: The teacher will be able to set a starting situation for the farm (for instance, very productive with high environmental impacts). He will then define objectives for the player, and the means to do it (game length, farm budget and so on). This last game mode will be fully customizable. Depending on chosen settings, the level of difficulty will vary. This will allow teachers to use the game with high school, BSc, MSc students or agricultural professionals. Finally, game users will be able to propose their custom scenarios to the online community. This will enrich the game and offer a larger diversity of pedagogical opportunities to players.

Other project activities and outputs

The main activity throughout this three-year project is to build the serious game. After a review on agroecological practices, a conceptual model will be established, highlighting the main components that will be represented in the game as well as their interactions. The mathematical model will then be realized. An external software company will conduct the conception of the graphical interface.

A tutorial and pedagogical resources will be created during the project. The game and pedagogical resources will be tested with students during the course of the project. Training events for professionnals and teachers will also be organized. The serious game, as well as all project results, will be freely available online in four languages (English, French, Italian and Polish) at the end of the project.

Description of the serious game

Overall description

The serious game will allow the player to pilot a dairy and crop farm. We chose this farming system because combining crops and livestock offers various agroecological levers to improve the sustainability of farming systems (Bonaudo et al., 2014). Moreover, it is a usual farming system found in all partner countries. A typical dairy and crop farm will be developed for each partner country, which will lead to four different farms, thus providing a larger variety of pedagogical activities and players experience. The diversity of partner countries will give the game a truly European dimension, which will be interesting for its use outside the partner countries.

The player will have to make her/his farm evolve by implementing various agroecological practices, in order to attain a defined objective. The play screen will represent a dairy and crop farm landscape. The player will be able to click on each of the landscape elements (fields, animals, farm buildings, tractors, hedges...) and choose from a list of available agroecological practices. Information will be available for each practice, as well as a description of its main effects. The possibility to implement practices will be regulated by working time and budget constraints, as well as by some necessary developments to access novel techniques, in order to reflect real constraints encountered by farmers. Steering indicators (technical, social, environmental and economic indicators) will be displayed on screen, allowing the player to assess the relevance his strategy and the distance from his objectives.

Model architecture

The architecture of the serious game will be based on six modules: soil, crops, animals, ecosystem, socio-economic aspects and steering indicators (Fig. 1). All these modules will be coupled together to exchange information, in order to ensure the systemic dimension of the farm. They will represent the main biophysical, social and economic aspects of an integrated crop and dairy farm. Major agroecological practices found in the scientific literature will be implemented in the game. For each of these practices, the effects on each module will be described. Some important synergetic effects will also be described.

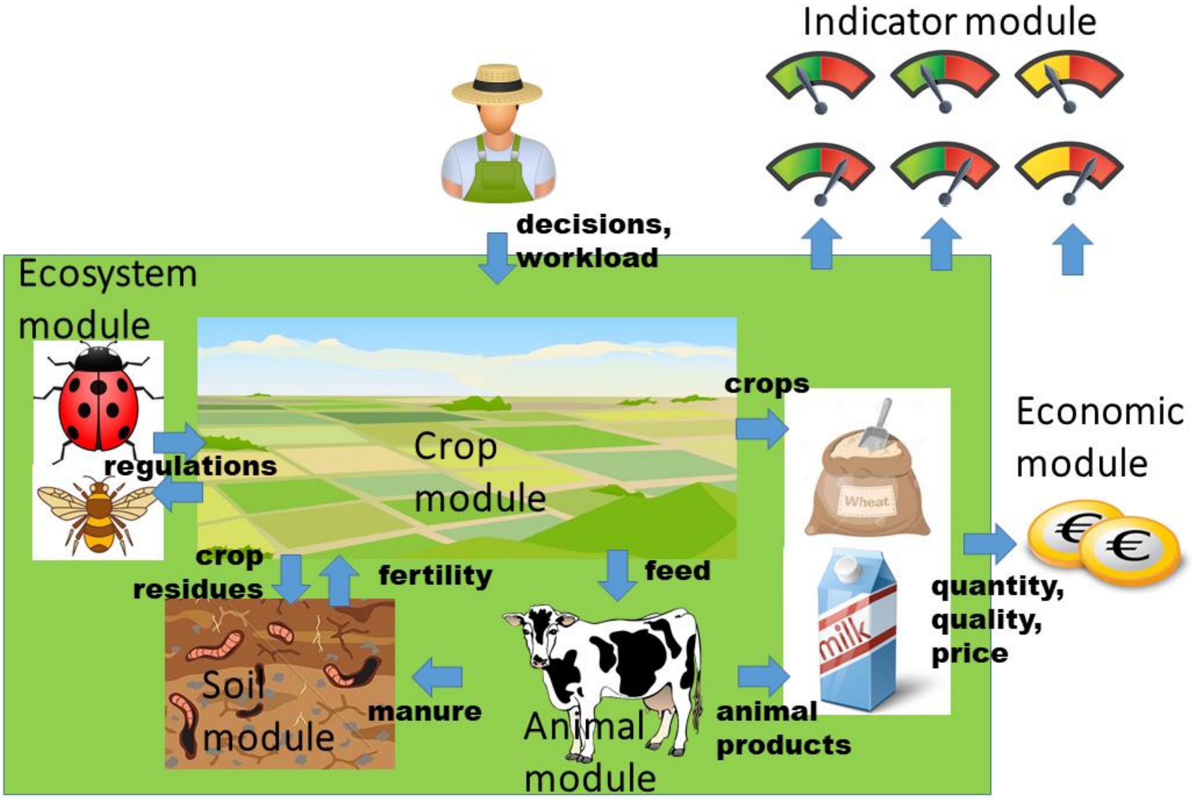

Figure 1. Representation of the serious game structure

Modules will be based on mathematical equations and/or expert knowledge but will remain simple, in order to ensure the game playability. The set of variables and parameters of each module as well as available farm practices and ecosystem services will be specific for each country.

The soil module will represent the main processes occurring in the soil under various agricultural practices. Water, nutrient and carbon cycles (including gaseous emissions, carbon storage and lixiviation) nutrient availability to plants, soil physical properties and soil biodiversity will be represented. They will be influenced by several practices, including fertilization and crop protection practices, organic matter recycling, soil tillage, as well as the diversity of crops in time and space.

The crop module will represent the major crops and forages, including grasslands, found in dairy farms of the four partner countries. It will calculate crop production and quality based on the soil and climate characteristics and farming practices (fertilizer use, crop rotations, weed, pest and disease management...), and the environmental impacts linked to crop production. Mixed crops, crop co-products such as straw, energy crops and agroforestry will be included in this submodel, as well as farm equipment for crops.

The animal module will represent the herd structure and dynamics (fertility, calving period and interval, culling rate…), feed requirements throughout the year, milk and meat production, animal health, manure production and use, animal housing and equipment, and environmental impacts from animals. Only dairy cows are envisaged for the moment, but different animal breeds will be available. Methanization will be part of this submodel.

The ecosystem module will represent ecosystem services other than production (which is represented in crop and animal submodels) and recycling of nutrients (which is represented in the soil submodel). It will thus represent the hedges, field margins, wetlands and other spaces of interest for ecosystem services. These services will include among others pollination, pests and disease control, genetic resources preservation and cultural services (recreation, landscape).

The economic module will represent the financial functioning of the farm: purchases, sales, investment capacity, loans. Prices will be influenced by product quality and labelling (organic for instance), as well as commercial outlets. Price variations will also occur to represent market volatility, which will provide an insight of the farming system resilience. The social submodel will estimate the workload of farmers, and represent the relationships between the farmer and other actors (consumers, neighbors, other farmers and counsellors…). Farmer's education, risk adversity, gender and age-based differences will not be explicitly considered are they are embedded in the player's strategy. However, this will represent an important topic of discussion with the teacher at the end of the simulation.

Finally, the indicator module will calculate a set of indicators related to technical management, as well as environmental, social and economic sustainability. It will use information from all other modules to provide a systemic view of the farming system and its evolutions.

Discussion

Insights from existing serious games

There is a wide body of scientific literature dealing with serious games (Connoly et al., 2012). However, a bibliographic review with the keywords "serious game" and "farm" or "farming" on Web of Sience, Google Scholar and Google did not allow us to identify any serious game allowing players to manage a realistic crop and livestock farming system with a technical and systemic (economic, social and environmental) approach. This is a strong point in favor of our project. Several interesting serious games about farming were nonetheless identified, and other serious games not related to farming were also studied. This chapter does not provide an exhaustive review on existing farming serious games, but rather highlights the features and that we considered interesting for our project.

Third World Farmer (https://3rdworldfarmer.org) is an online game at farm scale. It has been developed as a student project from the University of Copenhagen in 2005, and has been continuously improved since then. Its main goal is to to raise awareness about hunger and poverty-related issues in third world farming. The player experiences the difficulties of being a small African farmer seeking to improve his family's living standard while being confronted to bad harvests, corruption, guerrilla and other events. The agronomic and agroecological content of the game is very simple and cannot be a source of inspiration for SEGAE. The strengths of this game are its great playability and its wide use in academia, which has allowed millions of students to play the game over the years. We plan to get inspiration from its intuitive features (simple menu, clear pictograms, help in pop-up windows…) in our project.

Engele (http://www.rmtelevagesenvironnement.org/engele-rmt.htm) is a pig farm simulator created by French research centers, agricultural professionals and teachers. It has been developed in 2012 to help students and farmers understand the links between pig production and its environmental impacts (Dourmad et al., 2013) and has been mostly used in French agricultural high schools since then. This game is based on a mathematical model linking pig feeding, meat production, excretion and manure management. The technical options of this game offer a level of detail that we would really like to reach in our project, but it is focused on pig production and thus crop management possibilities are limited. Moreover, there is no socio-economic dimension in the game. We plan to re-use the agile methodology that was used to develop this game with a software company, as well as the custom scenario approach that is also provided. The cost of the game was mostly driven by 3D graphic design, which does not seem an essential feature to other serious games, so we decided to put more emphasis on playability and gamification and less in graphic design.

The Forage Rummy (Martin et al., 2011) is a board game supported by a computer model built with Microsoft Excel. Its goal is to offer a discussion tool between farm advisors and farmers in order to test and evaluate modifications of their livestock system, feeding management and cropping and forage system. It is thus not exactly a serious game, but rather a decision support system. However, the conceptual model used in the tool is very inspiring: rather than a detailed and complex mechanistic biophysical model, it is based on a simple model relying on empirical data from experts. It thus requires very little parameterization data, and is easier to communicate to players (Sautier et al., 2012).

The RESORTES board game (Speelman and García-Barrios, 2010b) deals with land-use planning in an agricultural landscape. It is a cooperative game aimed at fostering exchange and discussion between smallholder farmers and other community actors. Although the nature and goals of this serious game are very different from our project, it is important to note that the game combines economic, social and environmental evaluation of farmers strategies in a unique scoring system (Speelman et al., 2014) that could be inspiring for our sustainability assessment system.

Finally, Clim'Way (http://climcity.cap-sciences.net) is an online serious game created in 2008 by a French science of scientific culture to raise awareness about energy consumption and greenhouse gas emissions reduction as well as adaptation to climate change in various sectors of activity, from industry to transport and agriculture. This serious game is inspired from the well known SimCity© video game. Although this game is not focused on agriculture, the graphic settings are intuitive, and the indicators are easy to follow. Moreover, each action is documented with a short pedagogical notice, highlighting the most important effects of the action and leading to more detailed information. We think that these features could be interesting in our game.

Limits of our games approach

There are several limitations to serious games approaches. The major limitation that we identified is to find the adequate equilibrium between simplification of the biophysical flows and interactions and the realism and reliability of the game simulations. This crucial issue led us to a conceptual model with a limited number of choices for each action. For instance, only 3 choices will be offered regarding tillage : systematic tillage, occasional tillage, and no-till. Some features and interactions will not be represented in our game : as an example, we decided to evaluate the interactions between farm management practices and functional biodiversity, but not on all biodiversity. By making these choices and giving this information to players, we hope to keep the model simple while realistic and attractive.

Another important limitation is the management of uncertainty. We plan to include some random events, such as climatic hazards, pest outbreaks and economic fluctuations that will introduce some uncertainty in the game. But for the sake of simplicity, we do not plan to include stochastic distributions of parameters: one action in one particular context will always lead to the same result. Yet it is well known that farm practices have very variable effects, and that interactions between system components can vary greatly, sometimes from positive to negative effects. This unsolved limitation highlights the fact that a session of serious game should also include a critical discussion of results with the teacher/trainer.

Another limitation in the model development is to adapt it to our different publics, from secondary students to agriculture professionals. We chose not to build a detailed decision support system for farm advisors, but rather a serious game about systemic thinking and agroecological practices. It is important to make this point very clear from the start with the players. Experienced professionals will probably spend less time individually playing the game, and more time on a discussion about how a systemic vision of the farm can modify their work practices. While students will be able to spend more time on the game and learn about the effects of various practices on the system indicators. So we are confident that the game will be usable with various publics with an adapted pedagogical program. This feeling is supported by the fact that Aqua Republica (http://aquarepublica.com/), a serious game dealing with water issues, includes a version for middle school children, a version for adult awareness raising and a version for stakeholder participation in real-life watershed management base on the same model (Chew et al., 2015).

Finally, a technical limitation is the cost and feasibility of maintenance and evolution of the game software to keep pace with rapidly changing technologies (smartphone, tablet) and computer software, the improvement in scientific knowledge and the development of new farming practices. To deal with this issue, we chose to give access (in an advanced user menu) to all game parameters in order to modify them according to new knowledge or in a different context. We also decided that the development of the program will be done with a common programming language, and that the code will be open-source in order to allow various users to propose improvements and modifications.

Conclusion and perspectives

Agroecology seems a relevant answer to many issues faced by today's agriculture. Comprehensive tools for awareness-raising and education are needed for both the academic and professional stakeholders. Our serious game is designed in this perspective, based on several interesting examples. Its pedagogical possibilities will allow teachers to use it with a large diversity of publics and various pedagogical objectives throughout Europe. We hope that this innovative tool will help students and professionals better understanding the holistic approach needed to improve the sustainability of farming systems, learning about the effects of various agroecological practices, but also developing strategic and creative skills and a desire to keep on learning. Despite their pedagogical interests, it should be stressed that serious games also present important limitations that have to be identified and discussed with players.

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References

Altieri, M. A. (1995) *Agroecology: the science of sustainable agriculture* (2nd Edition). Intermediate Technology Publications Ltd.

Bommarco, R., Kleijn, D., & Potts, S.G. (2013) Ecological intensification: harnessing ecosystem services for food security. *Trends in ecology & evolution*, 28(4): 230-238.

Bonaudo, T., Bendahan, A. B., Sabatier, R., Ryschawy, J., Bellon, S., Leger, F., Magda, D., & Tichit, M. (2014) Agroecological principles for the redesign of integrated crop–livestock systems. *European Journal of Agronomy*, 57: 43-51.

Chew, C., Lloyd, G. J., & Knudsen, E. (2015). Capacity building in water with serious games. *Subconscious Learning via Games and Social Media* (pp. 27-43). Springer, Singapore.

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers & Education*, 59(2), 661-686.

Dalgaard, T., Hutchings, N.J., & Porter, J.R. (2003) Agroecology, scaling and interdisciplinarity. *Agriculture, Ecosystems & Environment*, 100(1): 39-51.

Davis B., & Summers M. (2015) Applying Dale's Cone of Experience to increase learning and retention: A study of student learning in a foundational leadership course. *QScience Proceedings*, 2015:6

Debruyne, L., Triste, L., & Marchand, F. (2017) Is the Current Educational Landscape Suited for Agroecology? *23rd European Seminar on Extension and Education (ESEE), July 4-7, Chania, Greece.* 13p.

Dourmad, J.Y., Adji, K., Boulestreau-Boulay, A.L., Emeraud, L., & Espagnol, S. (2013) A 3D serious game for teaching the environmental sustainability of pig farming systems. *Book of Abstracts of* *the 64th Annual Meeting of the European Federation of Animal Science, August 26-30, Nantes, France,* 19: 572.

Francis, C.A., Lieblein, G., Breland, T.A., Salomonsson, L., Geber, U., Sriskandarajah, N., & Langer, V. (2008) Transdisciplinary research for a sustainable agriculture and food sector. *Agronomy Journal*, 100(3): 771-776.

Francis, C. A., Jordan, N., Porter, P., Breland, T. A., Lieblein, G., Salomonsson, L., DeHaan, R., Braden, I., & Langer, V. (2011). Innovative education in agroecology: Experiential learning for a sustainable agriculture. *Critical Reviews in Plant Sciences*, 30(1-2), 226-237.

Garnett, T., Appleby, M. C., Balmford, A., Bateman, I. J., Benton, T. G., Bloomer, P, Burlingame, B., Dawkins, M., Dolan, L., Fraser, D., Herrero, M., Hoffmann, I., Smith, P., Thornton, P.K., Toulmin, C., Vermeulen, S.J., & Godfray, H.C.J. (2013) Sustainable intensification in agriculture: premises and policies. *Science*, 341(6141): 33-34.

Gliessman, S.R. (2014) *Agroecology: the ecology of sustainable food systems.* CRC press.

Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M. & Toulmin, C. (2010) Food security: the challenge of feeding 9 billion people. *Science*, 327(5967): 812-818.

Kiili, K. (2005) Digital game-based learning: Towards an experiential gaming model. *The Internet and higher education*, 8(1): 13-24.

Lieblein, G., Østergaard, E., & Francis, C. (2004) Becoming an agroecologist through action education. *International Journal of Agricultural Sustainability*, 2(3): 147-153.

Martin, G., Felten, B., & Duru, M. (2011). Forage rummy: A game to support the participatory design of adapted livestock systems. *Environmental Modelling & Software*, 26(12), 1442-1453.

Ponisio, L.C., & Kremen, C. (2016) System-level approach needed to evaluate the transition to more sustainable agriculture. *Proceedings of the Royal Society B*, 283(1824): 20152913.

Qian, M., & Clark, K.R. (2016) Game-based Learning and 21st century skills: A review of recent research. *Computers in Human Behavior*, 63: 50-58.

Sautier, M., Martin, G., Martin-Clouaire, R., Piquet, M., & Duru, M. (2012). Participatory design of livestock systems adapted to new climatic conditions. *10th European IFSA Symposium, 1-4 July 2012, Aarhus, Denmark.* 9p.

Schroeder-Moreno, M.S. (2010) Enhancing Active and Interactive Learning Online-Lessons Learned from an Online Introductory Agroecology Course. *NACTA Journal*, 54(1): 21-30.

Speelman, E.N., García-Barrios, L.E., 2010b. The RESORTES (Redes Sociales y Ordenamiento Territorial Sustentable), unpublished boardgame.

Speelman, E. N., García-Barrios, L. E., Groot, J. C. J., & Tittonell, P. (2014). Gaming for smallholder participation in the design of more sustainable agricultural landscapes. *Agricultural Systems*, 126, 62-75.

Valley, W., Wittman, H., Jordan, N., Ahmed, S., & Galt, R. (2017) An emerging signature pedagogy for sustainable food systems education. *Renewable Agriculture and Food Systems*, 1-14.