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Agroecology: A Fertile Field for Human Computation

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ABSTRACT

Agroecology – the science of sustainable agriculture – offers a new and positive perspective for the creation of sustainable food systems. We argue that, from the outset, it is important to involve citizens in this development to create the necessary, bottom-up support for change in agriculture and to re-establish the ties between food production and consumption. Human Computation and Citizen Science offer opportunities to include citizens in the planning, monitoring and evaluation of agro-ecosystems. In the P2P Food Lab project, we also seek new ways to engage them more creatively by setting up a shared online/offline platform in which they can learn, practice, innovate, and share observations on agroecological techniques. In this Brief we give a descriptive account of our ongoing work on this agroecology and HCI application.

1. INTRODUCTION

P2P Food Lab's aims are to empower citizens to develop innovative and sustainable solutions for the growing, harvesting, distributing, and recycling of food and food-related items. We currently focus on the first phase of the food system: growing/production. When it comes to growing food, we are exploring how to develop a platform to involve amateur gardeners in the documentation and measurement of good practices for sustainable food production, and develop the *Free* technology that supports it. We ran an experiment in which a group of participants grow a selection of seeds on a small surface of $1m^2$. They document the plant growth using sensor data and weekly pictures. The associated web site is used to share this data and stimulate collaborative practices. The long term goal is to evolve our platform into a tool to educate about agroecology, to stimulate playful innovation through shared challenges, and involve citizens in the management of larger agroecological systems. In this sense, the project is related to field of participative, environmental monitoring (1; 2). The current Brief discusses our motivation and our ongoing exploration to find the combination of content (protocols, shared challenges), technology (sensors, apps), and social interaction (online, local) that enables citizens to contribute meaningfully to the field of agroecology.

2. AGROECOLOGY

In the aftermath of WWII, the Green Revolution assured an excess of food in economically developed countries. However, it brought with it many of the problems facing our current food system, from a decrease in biodiversity and soil fertility to high levels of pollution and high emissions of greenhouse gases (3). At the same time, it has had the side effect of divorcing citizens from the processes of food production and processing. This has occurred in parallel with an increase of food waste, unhealthy diets, obesity, and cardio-vascular diseases. The high industry concentration of agricultural supplies and retail reinforces a business-as-usual situation that leaves little space for experimentation.

P2P Food Lab wants to reverse these trends by involving people in an agriculture that is regenerative to the soil, biodiversity and health while minimizing pollution. We have identified agroecology as this form. Agroecology, sometimes summarized as the science of sustainable agriculture, "has been proposed as a new scientific discipline that defines, classifies and studies agricultural systems from an ecological and socio-economic perspective" (4), see also (5; 6).

Agroecological strategy involves the use of ecologically based management. Enhancing biodiversity is a key aspect. It aids in nutrient cycling, soil structure, disease and pest control. Intercropping (spatial diversity), crop rotation (temporal diversity) and landscape topography are used to create an integrated pest management system combining biological, physical, cultural and genetic measures as an alternative to chemical pesticides (3).

FAO Director-General José Graziano da Silva noted that "agroecology continues to grow, both in science and in policies." The largest international coalition of peasant farmers, La Via Campesina, representing some 300 million small-scale farmers, has formally recognized and adopted agroecology as its preferred paradigm for rural development.

Agroecological farming increased from 23,000 hectares in 1996 to 403,000 in 2008 in Ecuador, generating $395m and creating 172,000 jobs (7). A study of 40 projects and programs in 20 African countries where agroecology has been employed from the 1990's-2000's supports these figures. The study documented benefits for 10.39 million farmers and their families and improvements on approximately 12.75 million ha. yields per hectare rose on average by 2.13-fold and diversification has brought about the emergence of a range of new crops and livestock (8). European governments have also started programs to support agroecology[1].

Olivier de Schutter's, UN's Special Rapporteur on the Right to Food, points to evidence of how agroecology has the potential to dramatically increase yields. In his 2010 report, he cites a study of 286 agroecological projects, which found that yields increased by an average of 79%. He concludes that small-scale farmers can double food production within 10 years in critical regions by using

[1] See for example, France's commitment to agroecology: http://agriculture.gouv.fr/agriculture-et-foret/projet-agro-ecologique

ecological methods. Based on an extensive review of the recent scientific literature, the study calls for a fundamental shift towards agroecology (9).

It is important to note that the term agroecology can mean several things. Wezel et al. document how it was first understood as a scientific discipline. Its meaning then evolved to denote also a farming practice and a social movement (5). In terms of scale, agroecology grew from a focus on plots to considering complete food systems. Gliessman also puts a strong accent on the larger social aspect. He considers that a popular support and appropriate local socio-economic structures have to be in place for agroecology to develop itself further (3).

3. AGROECOLOGY AND HUMAN COMPUTATION

We see four good reasons to involve citizens in agroecology through Human Computation and Citizen Science. First, in order to support the development of agroecology, a wider understanding of its principles is required. This support can be obtained through various actions, including educational and awareness programs. Our approach, discussed below, is to seek the introduction of a playful and creative platform that allows to addresses many of the principles of agroecological practices.

Second, agroecology is closely related to ecological management and to adaptive management (10; 11). Adaptive management uses learning-based decisions processes to handle the uncertainty inherent in complex systems such as agro-ecological systems. To be successful, the organization managing the natural resource must be flexible, collaborative and inclusive. In the case of food systems, citizens should take part in the adaptive management processes as they are one of the main stakeholders. What this means concretely is that the planning, monitoring, and evaluation processes for agro-ecosystems should be as open as possible to their participation (12).

A third reason for the need of their involvement is that automation is gaining ground in conventional agriculture and, in the foreseeable future, automation will surely extend to agroecology. It is important, however, that humans remain in the loop of the automated processes. Without their surveillance there is the temptation to push for farming methods that greatly reduce the complexity. A more evolved method will combine the benefits of algorithmic procedures with the capacity of humans to make nuanced evaluations and spot problems early.

The last reason is that many cropping systems proposed for agroecology can be applied on small surfaces by amateur gardeners as well as on larger surfaces by professional growers (13; 14). Innovations by amateur gardeners are therefore relevant for agroecological farmers and, vice verse, techniques introduced by farmers can be further tested by home growers. As any gardener will confirm, each cropping season is an new experiment that involves the preparation of the soil, the selection and organization of the varieties, the timing of the actions, the management of the pests, and the production of compost. The observations and decisions made by millions of gardeners can be aggregated to obtain best practices or to handle ecosystems on larger scales.

These three reason motivate our work to seek out solutions for agroecology based on Human Computation, Citizen Science, and Community Memory (15). In addition, we feel that the involvement of citizen is important for the following reasons that are relevant to the topic of discussion:

– **Educate**: Human Computation and Citizen Science are a great way to raise awareness of and engagement with environmental issues such as soil fertility and biodiversity. Involving people in

food production processes serves to reverse their separation from it.
- **Engage**: Many people feel ill at ease with the current environmental situation but don't know how they can contribute to make a change. Participating in small agroecological experiments provides people with a constructive and accessible activity to develop new solutions.
- **Entertain**: For many people, gardening is a rewarding activity in itself and they have an intrinsic motivation to participate. In addition, using online social networking tools we can increase the entertainment value of gardening through challenges and experiments.
- **Invent**: The alternative cropping techniques and their study will require developing new technologies, measurement instruments, and analysis techniques. The rapid evolution of Free Hardware, FabLabs, and bio-hacker spaces opens up new possibilities to develop these technologies collaboratively.

Citizen Science is already widely used to monitoring biodiversity with important results (17). Two existing experiments go beyond the contribution of observations by citizens. In a more involving experiment, Dr Naomi van der Velden sent 50 collections of seeds to volunteers to study the productivity of mixed cultures versus monocultures (18). Also Cornell's YardMap Network, aims to include citizens in the debate on sustainable gardening and biodiversity using a playful online platform (23).

4. P2P FOOD LAB

P2P Food Lab is a research project that aims at the development of a platform that facilitates the involvement of citizens in the debate on and the establishment of sustainable agriculture. P2P Food Lab wants to maximize the number of people who can be involved by minimizing limitations for participation. To this end, we keep the focus on small-scale *micro-agriculture* with plot sizes of about $1m^2$. As Alan Chadwick, a leading figure in bio-intensive farming in the US in the 70's, said: "Just grow one small area, and do it well. Then, once you get it right, grow more" (cited in (14)).

4.1. P2P Food Lab Starter Kit

In our first experiment, during Summer 2014, we developed a "Starter Kit" for micro-agriculture that consisted of a small, Internet-connected greenhouse. A sensor box was placed inside the greenhouse that took daily images of the crops and measured the air temperature, air humidity, and sunlight (Fig.1). The sensor box was built using off-the-shelf components such as Arduino, Raspberry Pi and standard webcams[2]. The goal of the connected greenhouse was to create an on-line social network of participants and gardeners, and use the sensors for the evaluation of plant growth.

The Starter Kit was a stepping stone that helped us develop the sensor technology. However, the project had several drawbacks. The kit was too complex to build and too expensive to engage many people. We also needed to give participants clearer guidelines if we wanted to obtain reusable data. To achieve this, we simplified the requirements for participation in Summer 2015, in the new experiment called "CitizenSeeds".

[2]See our wiki for more information: https://p2pfoodlab.net/wiki/

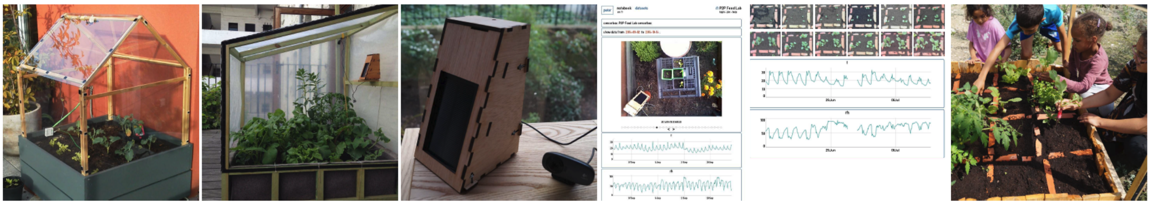

Figure 1. ***From left to right: 1) The first P2P Food Lab greenhouse near Paris, 2) Subsequent version of the greenhouse in Brussels, 3) Sensor box with camera, 4) Screenshot from the web site, 5) Time-lapse of the radishes and weather data, 6) Children from participating school near Paris.***

Figure 2. ***From left to right: 1) The seeding calendar, 2) A 1.2×1.2m plot with seedlings, 3) Matrix of photos uploaded by participants, 4) Visualization of recorded environmental data.***

4.2. The CitizenSeeds Experiment

In "CitizenSeeds", participants only needed a mobile phone equiped with a camera and a $1m^2$ plot of land, either on plain soil or in a raised bed. We also defined a collection of seeds to plant and a fixed, shared planting schedule (Fig.2). These two elements greatly help in aligning the participants, comparing the data, and stimulating social interaction. To measure the environmental data (photosynthetically active radiation, air temperature, soil humidity) the participants had the option to use the Flower Power device produced by the company Parrot. They also had the possibility to buy soil for their plot to normalize the substrate used in the experiment. Few participants chose this option, however.

Participants are asked to upload photos of their plot and the vegetables once a week. About 80 people registered of whom about 30 contributed to the experiment. A single web page displays the states of the plots and the environmental data of the community[3].

For the exchange of additional information, we integrated a forum in the top section of the web page where people upload their weekly pictures. We also installed a framework for social networking, called Diaspora, to facilitate the discussion between participants. Because this year's group of participants was small the use of these communication tools remained low.

[3] See https://p2pfoodlab.net/CitizenSeeds/experiments/4.html

4.3. Future developments

The first experiments we very encouraging but we feel that we are still at the beginning of this endeavor. The main developments that we envision are as follows.

Low-tech sensors and Human Computation The use of sensors for participative, environmental projects face a number of challenges that many citizen scientists will recognize. Designing a sensor box to be built by the participants is not within everyone's reach. These solutions also remain fairly expensive because there is no economy of scale to produce them. The use of a commercial off-the-shelf sensors does not solve all problems. In our case, to download the data of the sensor device, a recent model of mobile phone equiped with Bluetooth 4 LE was required. Only about one third of the participants had such a phone. The data collection is also easily perturbed by small "errors": a light sensor that is covered by growing plant leaves, infrequent data collection which results in the loss of sensor values. But even if these problems are overcome, we found that the measurements of the common environmental parameters are insufficient to monitor the complexity of plant growth. Adding more sensors and more complex analysis techniques will add costs and complexity.

From these experiences, we feel that a better option may be to use low-tech sensing techniques and use, for example, the cameras of mobile phones to upload images of the measurements to an online platform. Quantitative data can be extracted from the image through the online analysis by humans.

Social network Although social networks are not directly related to Human Computation, they have become an indispensable tool to gather and motivate participants. The question remains whether we should rely on existing commercial networks with the risk of loosing access to the valuable discussions, or whether a new network should be created specifically for the targeted project. A new social network requires considerable effort to manage the community. But it may also strengthen their ties with the project (23).

Broaden participation To reach out to many people, different types of engagement should be made possible:

Community memory: In the first type of engagement, participants share experiences and participate in discussions online with little pre-defined structure on the data they submit. Forums, discussion groups and photo sharing are some of the common tools in this first type of engagement. It is also an important tool to keep track of the history of a community and to strengthen its identity (16; 19).

Collaborative problem solving: ICT tools can also be used to collect structured data, such as listing the problems encountered and the possible solutions proposed by community members. This sharing of experiences helps to build inventories of good practices and doing it online allows for a rapid evolution of cropping techniques within communities. Collaborative problem solving is one of the factors that helped the rapid growth of agroecological practices throughout Latin America (21; 22).

Playful innovation: Participants can compete in constructive challenges. They must document their solutions so that everyone can benefit from their innovations. Examples of challenges include the local harvesting of the energy needed to power the sensor networks.

Citizen science: Experiments can be designed that have a well-defined protocol and are analyzed in order to obtain repeatable and quantifiable results. These experiments should be used to give further strength to good practices that have been observed and should be embedded in a continuing discussion between practitioners and the scientific community (18).

Human Computation: Well-defined problems that are hard to solve computationally are submitted to the community for analysis.

Human Computation and Adaptive Management Further experimenting is needed to design systems that include citizen in the adaptive management of agro-ecosystems. Their involvement in monitoring is already established through the many Citizen Science projects where citizens provide data (17) or analyze environmental data (24). It is easy to imagine how automated monitoring systems create micro-tasks that will be evaluated by humans, for example, to inspect photos for the early detection of plant stress, or count the number of pollinators that visit a flower in a video to produce an indicator of biodiversity (25). These analyses then feed back into farm or landscape management system.

The evaluation and planning for agro-systems is generally still done by experts. Both these phases could be extended to include citizens, if guided by information systems that integrate domain-specific knowledge and evolve into what Michelucci calls problem-solving ecosystems (26).

5. CONCLUSION

Agroecology offers a hopeful perspective for sustainable food production. It introduces new challenges and it requires a change in how food systems are organized. Popular support and participation are not only useful but necessary to make these changes happen. Through combination of home food growing, social networking and shared experimenting/analysis, the P2P Food Lab can evolve into laboratory for small-scale agriculture and agroecology. It can be extended to include the most important aspects of sustainable food production: soil fertility, biodiversity, energy harvesting, crop selection, and composting. We hope that this brief provided new ideas and may stimulate further discussions on how we can reconnect citizens with the wonderful world of agroecology and sustainable food systems.

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