ÉVORA
2022 IFSA

DIGITAL BOOK OF PROCEEDINGS

14TH EUROPEAN IFSA SYMPOSIUM

FARMING SYSTEMS FACING CLIMATE CHANGE
AND RESOURCE CHALLENGES

8 – 14 APRIL, 2022, UNIVERSITY OF ÉVORA, PORTUGAL

THEME 3 – AGROECOLOGY AS A RESPONSE TO CLIMATE CHANGE

Agriculture faces many different challenges and has partly lost its connections with nature and with society. This led to several undesired and mostly unforeseen negative consequences. The search for more sustainable pathways for agriculture development has shifted the focus of attention from individual practices at field level towards the farm dimension, farm organisation (ex. in terms of autonomy), farm landscape cooperation (ex. in terms of biodiversity), and even food issues. In all cases, reconnections or new connections between agriculture and its environment (weather nature or society) must be redesigned and created.

iPES FOOD confirms: “What is required is a fundamentally different model of agriculture based on diversifying farms and farming landscapes, replacing chemical inputs, optimizing biodiversity and stimulating interactions between different species, as part of holistic strategies to build long-term fertility, healthy agro-ecosystems and secure livelihoods, i.e. ‘diversified agroecological systems’.”

CHARACTERIZATION OF DAIRY CATTLE HERD MANAGEMENT WHILE TRANSITIONING FROM PUREBRED BREEDING TO ROTATIONAL CROSSBREEDING.

Julien Quénon[a], Stéphane Ingrand[b], Marie-Angélina Magne[c]

[a] UMR AGIR, Université de Toulouse, INRA-INPT-ENSAT-EI PURPAN, France.
[b] Université Clermont Auvergne, AgroParis Tech, INRA, Irstea, VetAgro Sup, France.
[c] UMR AGIR, Université de Toulouse, ENSFEA, INRA, INPT, INP- EI Purpan, France.

Abstract: Using animal agrobiodiversity is considered as a promising lever to improve farm performances and its resilience. Some dairy cattle farmers adopt rotational crossbreeding to use genetic variability, heterosis and complementarities in dairy breed features. Although it has been increasing since 2010, dairy crossbreeding remains still rare in France, while it is quite common in USA and Ireland... Many studies deal with the performances of crossbred cows compared to purebred ones, for a wide range of schemes and performance criteria. However, little is known about how dairy farmers manage crossbreeding, particularly during the transition of the herd towards crossbreeding. Our study aims at characterizing dairy farmers herd management while they move from pure- bred breeding to rotational crossbreeding. We focused on the evolution of herd configuration management: crossbreeding, mating, turnover and culling practices. We interviewed 26 dairy farmers who have been using rotational crossbreeding for a long time and had at least 33% of their herds composed of crossbreds of second generation in 2018. Data were encoded to build 11 variables describing the evolution of farmer's practices for the period of transition, then processed by a multiple correspondence analysis and hierarchical clustering. Three transition pathways of herd management towards dairy crossbreeding were identified and structured along two main axes. The first axis differentiates farmers according to the rythm of crossbreeding implementation and the depth of change in herd configuration management practices in relation with the role of crossbreeding in the whole-farm dynamics: adopting a predefined crossbreeding scheme on a high number of inseminations in the herd to correct a fertility defect in cows without deteriorating milk performance vs. looking for a customized crossbreeding scheme to create a cow best suited to livestock system changes, even if it means reducing milk performance. The second axis differentiates farmers according to the evolution of herd's turnover practices in response to the effects of crossbreeding on cows' performances: regulating the overflow of crossbred heifers linked to the improvement of crossbred cow's fertility by switching from heifer purchases to sales and increasing industrial crossbreeding vs. increasing dairy crossbreeding insemination because it has only be used on a part of the herd or the rate at which it was set up has been slower. Our findings can be used to support dairy farmers' decision-making to move from purebred to crossbred herds. It also need to be matched by a characterization of herd performances while transitioning towards crossbreeding.

DYNAMICS OF AGRICULTURAL SYSTEMS FACING DISTURBANCES: DOES INTENSIFICATION LEVEL EXPLAIN RESILIENCE?

Dardonville M. [a,b], Bockstaller C. [c], Therond O. [d]

[a] LAE, Université de Lorraine, INRA, Colmar, France.
[b] Agrosolutions, France.
[c] LAE, Université de Lorraine, INRA, Colmar, France.
[d] LAE, Université de Lorraine, INRA, Colmar, France.

Abstract

Identifying the characteristics and properties that influence dynamics of agricultural systems - resilience, vulnerability and robustness - when disturbances occur remains a scientific challenge. More specifically, intensification has a major influence on yield levels, but its effect on yield dynamics is still under discussion, especially in the debate on conventional vs. organic agricultural models. We present results of a systematic review of peer-reviewed studies that quantitatively assessed dynamics of agricultural systems in terms of vulnerability, resilience, and robustness (VRR). We queried the Web of Science and systematically sorted the co-occurrence of terms with VOSviewer to exclude articles outside the intended scope (2 reviewers). We identified 11 articles that evaluated effects of intensification in temperate zones and at different organizational levels: field, farm and region. We analyzed the results of each study through detailed characterization: VRR to what (disturbance), VRR when and where (spatial and temporal extent and resolution), VRR of what (studied system), VRR of which attribute (performance to maintain) and VRR due to which endogenous or exogenous properties (explanatory factors). We summarized results by disturbance, type of production, organizational level and performance attribute. Studies varied greatly in type of production (crops, livestock, vineyards, grasslands) and performance attribute (yield, economic efficiency). We show that crop intensification (intensification of practices and socio-economic characteristics) is not effective at mitigating negative effects of climate change on the dynamics of yield. In the short and medium term, the appropriateness of the production situation (crop, management, soil, climate) and resource availability and dynamics is crucial for designing resilient agricultural systems. In the long term, natural capital must be conserved to ensure agricultural production. We also believe that dynamics must be compared at the same level of production and intensification of practices. Finally, we identify that low intensification levels may result in desired dynamics of yield, and thus resilience, by compromising on high yields to address resource depletion and the degradation of natural capital.

Introduction

To control factors that limit and decrease agricultural production, modern agriculture has replaced ecosystem services with exogenous inputs such as fertilizers, irrigation, tillage and pesticides (Duru et al., 2015; Rist et al., 2014). This has resulted in human-modified and intensive agricultural systems that are relatively independent of their natural biophysical context (Rist et al., 2014) and harm the environment (Emmerson et al., 2016). For example, the development of irrigation helped to manage drought or high evapotranspiration and consequently increase yields (Zaveri and Lobell, 2019), but the subsequent depletion of water resources can lead to substantial local to regional water scarcity.

While it is well known that intensification has positive impacts on productivity and often negative impacts on the environment (Therond et al., 2017), few studies have analyzed its effects on the dynamics of the performances of agricultural systems. The recent meta-analysis of Knapp and van der Heijden (2018) on the effect of conventional, organic and conservation agriculture on yield stability showed contrasting effects depending on the crop, pedoclimatic conditions and intensification level, and on the metric used to analyze stability (standard deviation (SD) or coefficient of variation (CV); see also Li et al. (2019)). They highlight that the causes of yield stability remain unexplored. Kirchmann et al. (2016) indicate that comparing agricultural systems, such as conventional and organic, requires sound "conditions for equitable evaluations…to avoid biased design, inappropriate interpretations and flawed conclusions" (see also Gattinger et al. (2012)). Therond et al. (2017) point out that conventional agriculture, like organic agriculture, covers a great diversity of cropping systems and thus the true determinants of performances (including dynamics).

Recent key studies have focused on effects of diversity on dynamics of agricultural systems (Dardonville et al., submitted; Wang et al., 2019). To our knowledge, however, there is no summary of effects of intensification that addresses problems related to comparing broad categories such as conventional vs. organic agriculture. Consequently, we performed a systematic review of peer-reviewed articles that quantified effects of intensification on the vulnerability, resilience and robustness (VRR) – i.e. dynamics – of agricultural systems facing climatic and economic disturbances. This paper presents the main results of the review and discusses them in light of recent studies that address these issues. This analysis complements those of effects of diversity on VRR (Dardonville et al., submitted) and of the nature of studies that investigate VRR of agricultural systems (Dardonville et al., submitted).

Methods

To identify relevant studies, we ran the following query [vulnerability, resilience or robustness × agricultural system × quantitative evaluation] on the Web of Science Core Collection (WoS) for English peer-reviewed articles from January 1988 to July 2018):

TS = ((vulnerabilit OR resilien* OR robustness) AND (agri* OR agro* OR crop* OR farm* OR grass* OR pastor*) AND (indicator* OR evaluat* OR quantitativ* OR quantif* OR model* OR simulat* OR decrease OR increase OR assess*))*

The search initially identified 10,635 articles. After focusing on articles involving temperate climate zones, to collect results with similar ecological and socio-economic functioning, 3,542 articles remained. To exclude studies outside the scope of the review, we first sorted by journal and WoS category. We then used VOSviewer software to systematically sort the studies based on the co-occurrence of terms (n=10) to identify terms that excluded studies outside the scope (1,434 articles remained). Finally, two reviewers read the title and abstract of each remaining article, which yielded 37 articles that quantified the VRR of agricultural systems in temperate zones at the field, farm or regional level. The sub-sample of articles that addressed effects of intensification on VRR was analyzed for the present review (11 articles).

To summarize the results of the articles, we used the generic analytical framework developed by Dardonville et al. (submitted). For each article, we specified (i) the disturbance that occurred (VRR "*to what disturbance*"), (ii) the spatial and temporal resolution and extent of the study (VRR "*when and where*"), (iii) the type and organizational level of the agricultural system investigated (VRR "*of what agricultural system*"), the performance attribute that was important to maintain (VRR "*for which performance attribute*"), whose dynamics were described using criteria of dynamics (e.g. variability, trend), and the endogenous or exogenous characteristics and properties of agricultural systems that resulted in VRR (VRR "*due to which explanatory factors*").

Each result of each article was extracted and homogenously coded for each combination of disturbance, type of production, organizational level, performance attribute, criterion of dynamics and explanatory factor. The analysis yielded 145 results from 11 articles that focused on intensification (of agricultural practices or socio-economic levels) as an explanatory factor (*Table S 1*).

Results

Only 11 articles were identified that quantitatively addressed effects of intensification on the VRR of agricultural systems. Five articles (56 results) focused on crop systems, three (47 results) on livestock systems, one on grassland systems (2 results), one on vineyard systems (35 results) and one on all agricultural systems (3 results). The articles varied greatly in the type of agricultural system (crop, livestock, grassland, vineyard), organizational level (field, farm, region) and performance attribute (e.g. yield, economic efficiency, quality of production) (Dardonville et al., submitted). The three articles that studied livestock systems analyzed different performance attributes (economic efficiency of production, self-sufficiency in forage and ability to feed the herd each day, Bouttes et al., 2018; Martin and Magne, 2015; Sabatier et al., 2015). Focusing only on results with the same characteristics (i.e. performance attribute and type of production), we summarized those with intensification as an explanatory factor for yield performance (9 of the 11 articles) of crop systems (5 of the 11 articles) when climate variability and change occurs (10 of the 11 articles). Consequently, we focused on five of the 11 articles (i.e. 56 of the 145 results) that studied crop yields for systems subjected to climate variability and change. Due to the small sample size, we performed cross-sectional analysis regardless of the organizational level. The five articles used different criteria for the dynamics of performance attributes: level, trend, variability and probability of exceeding a given threshold (i.e. high or low yield).

The explanatory factors of intensification described in these five studies were the intensity of practices (soil tillage, pesticide use, fertilizer use, irrigation), the level of capital, the economic size of the farm (quantity or value of outputs) and the quantity of labor (number of individuals in the household) (Gaudin et al., 2015; Matsushita et al., 2016; Reidsma and Ewert, 2008; Reidsma et al., 2008a; Urruty et al., 2017).

When analyzing effects of intensification factors on crop system dynamics (Figure 23), we distinguished effects on the yield itself (i.e. productivity) from those on the dynamics of yield (e.g. variability, trend). As expected, a clear positive effect was observed for intensification of agricultural practices (pesticide use, fertilization, use of soil amendments, irrigation and tillage) on yield at the field level (Gaudin et al., 2015; Urruty et al., 2017).

Effects of intensification factors on the dynamics of yield were less clear. Of the 145 results, 67% were negative or neutral, suggesting that intensification is not a relevant strategy to stabilize (i.e. achieve low variability in) yield, increase the trend in yield or have a high probability of a high yield.

Fertilization, pesticide use, irrigation and tillage had variable effects on the variability and trend in yields at field, farm and regional levels. For example, Urruty et al. (2017) showed that intensive fertilization had no effect on the trend in yield at the field level, while Matsushita et al. (2016) showed a positive effect of chemical fertilization on the short-term trend in yield at the regional level. Effects of fertilization and irrigation are difficult to distinguish since they are strongly related: increasing one leads to higher crop demand for the other. Reidsma et al. (2008a) showed that effects of fertilization and irrigation at the regional level depended on the country investigated.

Farm economic size had a negative effect on the variability (i.e. stabilization) in yield at the regional level (Reidsma and Ewert, 2008). However, the effects fluctuated between positive and negative for the trend in yield at the farm level (Reidsma et al., 2008a). Household size had no effect on the trend in yield at the regional level, but capital had a positive or neutral effect on it (Matsushita et al., 2016).

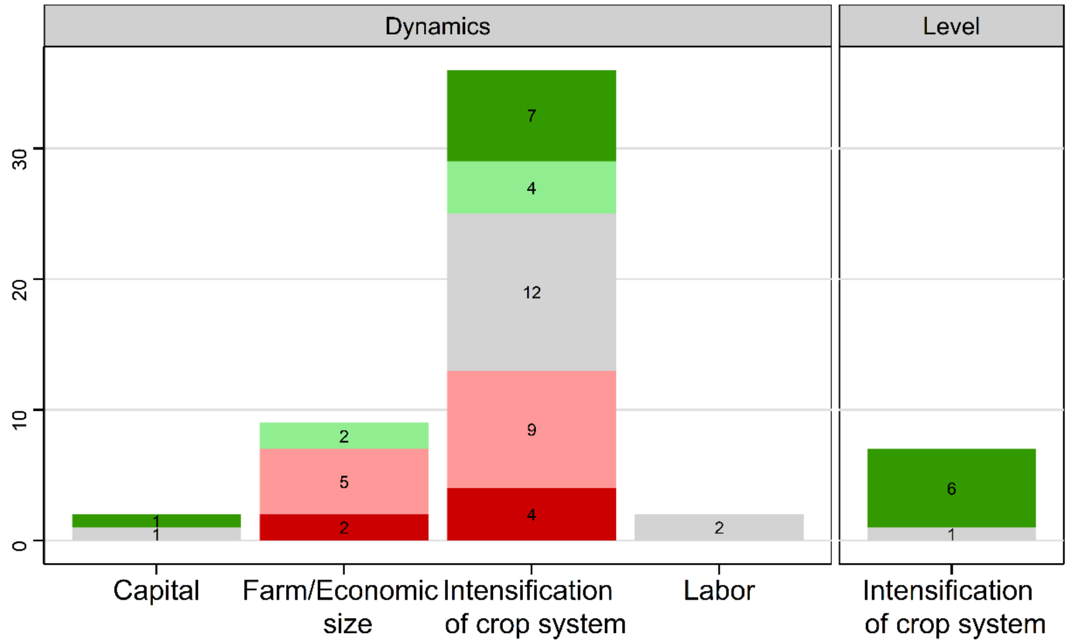


Figure 23. Number of results indicating the direction of the effect of climate variability and change and economic disturbance on the desired level (high) and dynamics (resilient) of yield for crop systems. Desired dynamics include an increasing trend, low variability and high probability of a high yield. When differences in results could be tested statistically, they were considered significant at p<0.05.

Discussion

This review highlights that few articles tested whether intensification influences the VRR of agricultural systems. Only five articles remained when the corpus was reduced to those that studied the same set of characteristics. The articles addressed the classic subjects of effects of climatic and economic variability on yield performance in crop systems. Only one article each addressed grasslands or vineyards, while the three articles that addressed livestock systems could not be compared directly since each examined a different performance attribute. Nonetheless, we discuss their results in light of those for crop systems.

We found clear positive effects for intensification of input use (including tillage) on crop yield. Overall, however, we also found that input intensification was not effective at mitigating negative effects of climate change and economic variability on the dynamics of crop yield, regardless of the organizational level. These results agree with those for livestock systems. Bouttes et al. (2018) showed that intensification of practices (percentages of maize and concentrates in diets, stocking rate) in livestock systems resulted in a high yield but a decreasing trend in economic efficiency of production. Martin and Magne (2015) showed more variable results because the seasonality of climate events can favor or disfavor grazing-based or maize-silage-based (more intensive) systems. Sabatier et al. (2015) showed that a low stocking rate, and thus intensity of grazing, led to fewer overgrazing situations and thus less "collapse".

Similar to intensification of input use, intensification of capital and labor seemed to have no clear effect on the trend in yield, regardless of the organizational level. Reidsma and Ewert (2008) and Reidsma et al. (2008a) showed that farms with the largest economic outputs seemed more sensitive to high temperatures at the regional level, and to high temperatures and subsidies at the farm level. In these studies, the economic size of the farm can be considered a proxy of capital intensification, in the sense that larger economic size is usually based on a large farm area or quantity of equipment (Bardaji and Iraizoz, 2015).

Our results contribute to the general debate on intensification. As mentioned, effects of intensification on the dynamics of yield depend strongly on the “production situation” (Aubertot and Robin 2013). Reidsma et al. (2008b) showed that the effect of irrigation on yield depended mainly on water availability, fertilization level and crop type. Recently, Renard and Tilman (2019) revealed that yield stability is increased by irrigation, but more so by species diversity and even more so by diversity in crop functional groups (legume, cereal). They claim that diversification could be a better strategy for adapting to climate change than irrigation in countries where water is unaffordable or insufficient. This indicates that the type and management of crops must be adapted to local production situations, including (water) resources (Aubertot and Robin, 2013; Knapp and van der Heijden, 2018; Zaveri and Lobell, 2019).

The dynamics of yield can depend on the level of production (Knapp and van der Heijden, 2018; Reidsma et al., 2008b; Stampfli et al., 2018; Wang et al., 2019)(Figure 24). For example, Reidsma et al. (2008b) showed that farms with lower yields (and less intensification) were less sensitive to climate disturbance in regions that had already adapted to recurring drought and increasing temperatures (e.g. Mediterranean regions). For grasslands, Figure 7 of Wang et al. (2019) showed that higher productivity led to significantly higher variability (SD) in productivity. These results may be explained by effects of biomass quantity on demand for and availability of resources required for growth (Figure 24). Biomass quantity, associated with yield, determines a crop’s water and nutrient demands: the more biomass it has, the higher its water and nutrient demands are. The availability of soil water and nutrients determines whether these demands are met or not. Both demand for and availability of water and nutrients influence each other. When water is scarce, rainfed systems with high production are expected to be more sensitive to climate variability, which influences variability in soil water availability. If these systems are irrigated and water for irrigation is available, however, they can maintain high production. Addition of nutrients can also maintain production, but Rist et al. (2014) call this maintenance of resilience through human inputs “coerced resilience”.

Knapp and van der Heijden (2018), Li et al. (2019) and Wang et al. (2019) assert that results can differ depending on whether an absolute (i.e. SD) or relative (per unit of yield, i.e. CV) indicator of stability is used. For example, Knapp and van der Heijden (2018) showed that organic and conventional farming had the same absolute stability in production, but that organic farming had lower relative stability due to lower production (-16%). In their results, higher yield led to higher relative stability, which seems to contradict the theoretical principles mentioned previously about relations between yield and its dynamics. However, the authors did not test effects of irrigation or specify the type of disturbance (e.g. drought) that occurred during the study period of nearly 4 years. It is possible that the conventional and organic systems they compared did not have the same level of intensification (e.g. irrigation). Accordingly, when comparing the VRR of a system’s yields, it is necessary to consider its production level and crop management to ensure the analysis provides relevant results and avoids classic pitfalls when comparing systems that can differ greatly, such as conventional vs. organic (Kirchmann et al., 2016).

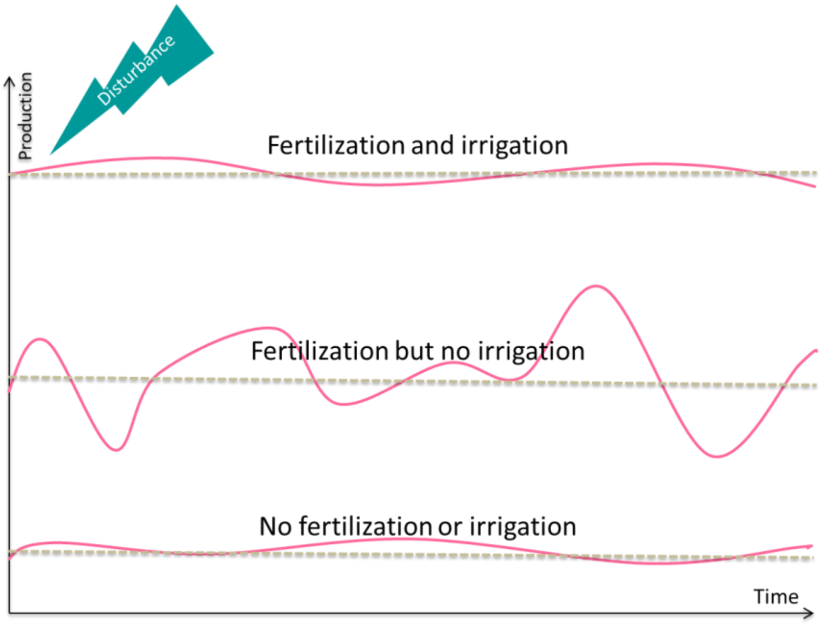


Figure 24. Diagram of the effect of production level and input intensification on production variability of a crop/grassland system at the field level due to resource availability (water, nutrients) for a given climate and soil. Without fertilization or irrigation (bottom), the associated low yield (low biomass) leads to low plant water demand that is met by soil water availability, and thus few climate effects on yield dynamics. With fertilization alone (middle), the higher yield and biomass increases plant water demand, making yield dynamics more sensitive to climate variability. With fertilization and irrigation (top), the higher yield and biomass increase plant water demand, which is met by irrigation, making yield nearly insensitive to climate variability (when irrigation water is not limited). It shows that if intensification of practices and production level are not considered, the top and bottom situations have similar yield dynamics (low sensitivity to climate variability) but different explanatory factors.

While some agricultural practices can provide desired dynamics of yield (e.g. positive trend) in the short term, it is necessary to consider long-term effects (Coomes et al., 2019). Matsushita et al. (2016) and Zaveri and Lobell (2019) showed that fertilization and irrigation each increase yield trends in the short term but that this effect tends to disappear in the longer term, perhaps due to yield stagnation. Consequently, short-term studies may be unable to identify or highlight middle- or long-term effects (Müller et al., 2016).

From a long-term perspective, the dynamics of soil natural capital and local resources (e.g. water) also have a major influence on the VRR of agricultural systems (Weyers and Gramig, 2017; Dardonville et al., submitted; Rist et al., 2014). Agricultural systems can exhibit VRR in the short term (e.g. season, year(s)) while experiencing degradation in soil natural capital and local resources due to intensive management and high production. For example, intensive use of groundwater for irrigation can result in a water shortage that renders irrigation more difficult (costlier) or even impossible (de Graaf et al., 2019). This also occurs in agricultural systems that use soil natural capital without recycling it, such as those that deplete soil organic matter (Drinkwater and Snapp, 2007) or organic systems that use the soil phosphorus reserve without supplying organic matter to replace the phosphorus exported (Kirchmann et al., 2009; Oelofse et al., 2010).

Although less intuitive, dynamics of resource use in agricultural systems can influence yield dynamics over the long term. Efficient resource acquisition during a given period (e.g. by exploring soil horizons (Barkaoui et al., 2016)) can initially lead to higher biomass production or stability (e.g. at the beginning of a season) but also greater depletion of soil resources. If the disturbance (e.g. drought) lasts or repeats, the empty resource reserves (e.g. soil water or nutrients) and the large amount of biomass with high water and nutrient demands will become factors influencing vulnerability in the medium term (e.g. at the end of the season) (Zavalloni et al., 2008).

Conclusion

Debate on the VRR of agricultural models is far from over, both on effects of intrinsic diversity (Dardonville et al., submitted) and those of intensifying production by adding organic or chemical inputs (as indicated by recent articles that compare conventional and organic systems). In this review, we summarized results of articles that explicitly quantified effects of intensification on the VRR of agricultural systems. The articles reviewed focused mainly on effects of climate on dynamics of yield. We show that intensification, although ensuring higher crop yields, is not always a reliable strategy to support resilience to disturbances. We highlight two key methodological issues when analyzing the VRR of agricultural systems. First, it is necessary to consider the production level (and its type) and the intensification level because they determine the dynamics of water and nutrient availability and thus the effects on production. Second, short-term studies may not be able to identify middle- or long-term effects of intensification on endogenous (e.g. soil water content) or exogenous (e.g. local water resources) resources and, in turn, on the VRR of agricultural systems. Intensification may have a positive effect in the short term, but degrading natural capital creates a negative feedback loop in the longer term (Dardonville et al., 2019; Rist et al., 2014). Accordingly, considering the characteristics of production situations (crop, management, soil, climate) and local resources is necessary to design resilient agricultural systems. More than ever, the question of intensification level and, more broadly, production level, needs to be reintegrated into the design process. Society needs to take a position about the objectives set for agricultural systems, deciding whether it is willing to sacrifice environmental quality and resilience in return for high yields. In the quest for agricultural sustainability in the most productive zones in the world, it may be necessary to redefine objectives: less focus on the production level and more focus on the desired dynamics, especially in the current context of climate change and increasingly extreme climatic events (Tittonell et al., 2016).

Supplementary material

Table S 1 : The 11 articles selected, detailing the type of production, organizational level, disturbance (categorized), performance attribute (categorized) and explanatory factors.

Reference	Prod. type	Org. level	Disturbance	Attribute	Explanatory factors
Bardaji and Iraizoz, (2015)	Wine	Farm	Climate variability and change	Yield, quality of production	Capital, labor, intensification of wine production, adaptation
Bouttes et al., (2018)	Mixed	Farm	Climate variability and change	Yield, economic efficiency of production	Economic performance, intensification of livestock system, composition effect, farm diversity, livestock structure
Gaudin et al., (2015)	Crop	Field	Climate variability and change	Yield	Diversity of rotation, intensification of crop system, composition effect
Martin and Magne, (2015)	Mixed	Farm	Climate variability and change	Self-sufficiency in forage	Intensification of livestock system, adaptation
Matsushita et al., (2016)	Crop	Region	Climate variability and change	Yield	Policies, composition effect, capital, intensification of crop system, labor, taxonomic diversity

Reidsma and Ewert (2008)	Crop	Region	Climate variability and change	Yield	Response diversity, farm diversity, farm/economic size, intensification of crop system
Reidsma et al., (2008b)	Crop	Farm	Climatic and economic variability	Yield	Intensification of crop system, farm/economic size, composition effect, adaptation, policies, farm/economic size
Sabatier et al., (2015a)	Grassland	Field	Climate variability and change	Ability to feed the herd each day	Continuous or rotational grazing, intensification of livestock system
Salvati, (2010)	All	Region	Land degradation	Yield	Composition effect, labor
Stampfli et al., (2018)	Grassland	Field	Drought	Yield	Intensification of grassland use
Urruty et al., (2017)	Crop	Field	Climate variability and change	Yield	Intensification of crop system, sowing practices, cultivar characteristics, diversity of rotation, composition effect, adaptation

References

Aubertot, J.-N., and Robin, M.-H. (2013). Injury Profile SIMulator, a Qualitative Aggregative Modelling Framework to Predict Crop Injury Profile as a Function of Cropping Practices, and the Abiotic and Biotic Environment. I. Conceptual Bases. PLoS ONE *8*, e73202.

Bardaji, I., and Iraizoz, B. (2015). Uneven responses to climate and market influencing the geography of high-quality wine production in Europe. Reg. Environ. Change *15*, 79–92.

Barkaoui, K., Roumet, C., and Volaire, F. (2016). Mean root trait more than root trait diversity determines drought resilience in native and cultivated Mediterranean grass mixtures. Agric. Ecosyst. Environ. *231*, 122–132.

Bouttes, M., San Cristobal, M., and Martin, G. (2018). Vulnerability to climatic and economic variability is mainly driven by farmers' practices on French organic dairy farms. Eur. J. Agron. *94*, 89–97.

Coomes, O.T., Barham, B.L., MacDonald, G.K., Ramankutty, N., and Chavas, J.-P. (2019). Leveraging total factor productivity growth for sustainable and resilient farming. Nat. Sustain. *2*, 22–28.

Dardonville, M., Bockstaller, C., Urruty, N., and Thérond, O. (2019). Influence of diversity and intensification level on resilience/vulnerability/robustness of agricultural systems. Submiss.

Drinkwater, L.E., and Snapp, S.S. (2007). Nutrients in agroecosystems : rethinking the management paradigm. Adv. Agron. *92*, 0065–2113.

Duru, M., Therond, O., Martin, G., Martin-Clouaire, R., Magne, M.-A., Justes, E., Journet, E.-P., Aubertot, J.-N., Savary, S., Bergez, J.-E., et al. (2015). How to implement biodiversity-based agriculture to enhance ecosystem services: a review. Agron. Sustain. Dev. *35*, 1259–1281.

Emmerson, M., Morales, M.B., Oñate, J.J., Batáry, P., Berendse, F., Liira, J., Aavik, T., Guerrero, I., Bommarco, R., Eggers, S., et al. (2016). How Agricultural Intensification Affects Biodiversity and Ecosystem Services. In Advances in Ecological Research, (Elsevier), pp. 43–97.

Gattinger, A., Muller, A., Haeni, M., Skinner, C., Fliessbach, A., Buchmann, N., Mader, P., Stolze, M., Smith, P., Scialabba, N.E.-H., et al. (2012). Enhanced top soil carbon stocks under organic farming. Proc. Natl. Acad. Sci. *109*, 18226–18231.

Gaudin, A.C.M., Tolhurst, T.N., Ker, A.P., Janovicek, K., Tortora, C., Martin, R.C., and Deen, W. (2015). Increasing Crop Diversity Mitigates Weather Variations and Improves Yield Stability. PLOS ONE *10*, e0113261.

de Graaf, I.E.M., Gleeson, T., (Rens) van Beek, L.P.H., Sutanudjaja, E.H., and Bierkens, M.F.P. (2019). Environmental flow limits to global groundwater pumping. Nature *574*, 90–94.

Kirchmann, H., Kätterer, T., and Bergström, L. (2009). Nutrient supply in organic agriculture–plant availability, sources and recycling. In Organic Crop Production–Ambitions and Limitations, (Springer), pp. 89–116.

Kirchmann, H., Kätterer, T., Bergström, L., Börjesson, G., and Bolinder, M.A. (2016). Flaws and criteria for design and evaluation of comparative organic and conventional cropping systems. Field Crops Res. *186*, 99–106.

Knapp, S., and van der Heijden, M.G.A. (2018). A global meta-analysis of yield stability in organic and conservation agriculture. Nat. Commun. *9*.

Li, M., Peterson, C.A., Tautges, N.E., Scow, K.M., and Gaudin, A.C.M. (2019). Yields and resilience outcomes of organic, cover crop, and conventional practices in a Mediterranean climate. Sci. Rep. *9*, 12283.

Martin, G., and Magne, M.A. (2015). Agricultural diversity to increase adaptive capacity and reduce vulnerability of livestock systems against weather variability – A farm-scale simulation study. Agric. Ecosyst. Environ. *199*, 301–311.

Matsushita, K., Yamane, F., and Asano, K. (2016). Linkage between crop diversity and agro-ecosystem resilience: Nonmonotonic agricultural response under alternate regimes. Ecol. Econ. *126*, 23–31.

Müller, F., Bergmann, M., Dannowski, R., Dippner, J.W., Gnauck, A., Haase, P., Jochimsen, M.C., Kasprzak, P., Kröncke, I., Kümmerlin, R., et al. (2016). Assessing resilience in long-term ecological data sets. Ecol. Indic. *65*, 10–43.

Oelofse, M., Høgh-Jensen, H., Abreu, L.S., Almeida, G.F., El-Araby, A., Hui, Q.Y., and de Neergaard, A. (2010). A comparative study of farm nutrient budgets and nutrient flows of certified organic and non-organic farms in China, Brazil and Egypt. Nutr. Cycl. Agroecosystems *87*, 455–470.

Reidsma, P., and Ewert, F. (2008). Regional Farm Diversity Can Reduce Vulnerability of Food Production to Climate Change. Ecol. Soc. *13*.

Reidsma, P., Oude Lansink, A., and Ewert, F. (2008a). Economic impacts of climatic variability and subsidies on European agriculture and observed adaptation strategies. Mitig. Adapt. Strateg. Glob. Change *14*, 35–59.

Reidsma, P., Ewert, F., Lansink, A.O., and Leemans, R. (2008b). Vulnerability and adaptation of European farmers: a multi-level analysis of yield and income responses to climate variability. Reg. Environ. Change *9*, 25.

Renard, D., and Tilman, D. (2019). National food production stabilized by crop diversity. Nature *571*, 257–260.

Rist, L., Felton, A., Nyström, M., Troell, M., Sponseller, R.A., Bengtsson, J., Österblom, H., Lindborg, R., Tidåker, P., Angeler, D.G., et al. (2014). Applying resilience thinking to production ecosystems. Ecosphere *5*, art73.

Sabatier, R., Oates, L.G., Brink, G.E., Bleier, J., and Jackson, R.D. (2015). Grazing in an Uncertain Environment: Modeling the Trade-Off between Production and Robustness. Agron. J. *107*, 257.

Salvati, L. (2010). Exploring the Relationship between Agricultural Productivity and Land Degradation in a Dry Region of Southern Europe. New Medit 35.

Stampfli, A., Bloor, J.M.G., Fischer, M., and Zeiter, M. (2018). High land-use intensity exacerbates shifts in grassland vegetation composition after severe experimental drought. Glob. Change Biol. *24*, 2021–2034.

Therond, O., Duru, M., Roger-Estrade, J., and Richard, G. (2017). A new analytical framework of farming system and agriculture model diversities. A review. Agron. Sustain. Dev. *37*.

Tittonell, P., Klerkx, L., Baudron, F., Félix, G.F., Ruggia, A., van Apeldoorn, D., Dogliotti, S., Mapfumo, P., and Rossing, W.A. (2016). Ecological intensification: local innovation to address global challenges. In Sustainable Agriculture Reviews, (Springer), pp. 1–34.

Urruty, N., Guyomard, H., Tailliez-Lefebvre, D., and Huyghe, C. (2017). Factors of winter wheat yield robustness in France under unfavourable weather conditions. Eur. J. Agron. *90*, 174–183.

Wang, Y., Cadotte, M.W., Chen, Y., Fraser, L.H., Zhang, Y., Huang, F., Luo, S., Shi, N., and Loreau, M. (2019). Global evidence of positive biodiversity effects on spatial ecosystem stability in natural grasslands. Nat. Commun. *10*, 3207.

Weyers, S.L., and Gramig, G. (2017). Low-Input and Intensified Crop Production Systems Effects on Soil Health and Environment. Soil Health Intensif. Agroecosytems 277–303.

Zavalloni, C., Gielen, B., Lemmens, C.M.H.M., Boeck, H.J.D., Blasi, S., Bergh, S.V. den, Nijs, I., and Ceulemans, R. (2008). Does a warmer climate with frequent mild water shortages protect grassland communities against a prolonged drought? Plant Soil *308*, 119–130.

Zaveri, E., and Lobell, D. (2019). The role of irrigation in changing wheat yields and heat sensitivity in India. Nat. Commun. *10*, 4144.

WHAT PROSPECTS FOR WORK IN AGRICULTURE IN THE WORLD?

Benoît Dedieu

INRAE, France

Abstract: 1.3 billion people work in agriculture (family farmers, salaried workers), i.e. 27% of the world's active population (2018). The number of agricultural workers is expected to remain stable in the coming years. Researches on work in agriculture remain rather disciplinary (economics dealing with labor markets, ergonomics with occupational health, sociologists with family farming and rural development or with the emergence of new figures of the profession…). Given these conditions, how can we produce a consolidated vision of the future of work in agriculture on a global scale? This was the objective of the 2nd International Symposium on Work in Agriculture entitled: 'Thinking the Future of Work in agriculture' (29 March – 1 April 2021). The dynamics of development of agriculture in the North (OECD) contrast with those in the Global South and thus raise different issues. Is an "agriculture without farmers" the future in the North (with salaried people in very big estates) considering the regular decrease of the number of farms and of active population? In the South, decent work (from the ILO definition) is still a target point for a significate part of the agricultural workforce. Beyond these deep differences, some issues appears to be transversal. The agroecological transition is everywhere a change in the farming style and a change in work organization, and in working conditions that have to be studied for different categories of workers (man, women, young, wage-earners). The digital revolution will certainly support the smart industrial agriculture but may be useful in agroecological – family situations. Migration is also a major phenomenon, from rural areas to cities, from poor countries to rich ones, often leading to precarious and hard-working jobs. What are the perspectives for a research agenda? First, decent and attractive employment is one key point for the future. Job satisfaction indicators (including self-fulfillment) are to be deepen notably to foster youth (in the South) and new incomers (OECD) interest for farming. Second, there is a need to considering the co-evolution of structural and social drivers (enlargement of farms, societal recognition of farmers…), on farming's new set of specifications (ecologization of practices) and on digital opportunities. Third agri-chains and territorial approaches of work should be enhanced.

BUILDING FARM SYSTEM RESILIENCE IN CANTON VAUD

Ulysse Le Goff, Dominique Barjolle, Johan Six

Institute of Agricultural Sciences, Swiss Federal Institute of Technology in Zurich (ETHZ)

Introduction

Climate change is a challenge that affects particularly agriculture, which both is a cause of it and suffers from it. The mission of agriculture is basically to produce enough food for today and for future generations. The mission does not change but is facing a new context, with the ending of certain resources, and new restrictions in relation with the urgent need to contribute to mitigate the climate change (Paris Agreement). Swiss agriculture within the global food system already faces and will face even more in the future, the consequences of climate change, such as climate shocks (droughts and floods for example) or price volatility. Indeed, the whole Alpine area is more exposed to changes and disturbances than other parts of Europe due to the global warming (Hoegh - Guldberg O et al., 2018).

To provide guidance for farmers and facilitators to cope with this harsh situation, it is necessary to embrace complexity and change. In the agricultural research and the practitioner sector, the "Resilience" framework gained influence recently to address this challenge (Darnhofer, 2014; Tendall et al., 2015). In an agricultural context, resilience thinking implies that farms can co-evolve with their context and adapt to a changing external system/environment (Darnhofer, Fairweather, & Moller, 2010). Thus, a resilient farm system can buffer shocks (Folke et al., 2010) or even transform into a new system, with new processes, when the old, existing system cannot be sustained any longer (Walker, Hollin, Carpenter, & Kinzig, 2004). This means that a resilient farm system will be able to persist over time albeit unforeseen shocks or disturbances, but will not necessarily rebound and return its original state as it will continue to evolve and adapt.

To strengthen farm system's resilience, it is important to identify and assess where vulnerabilities rely. However, resilience measurement is especially difficult for complex systems, and a Socio-Ecological System (SES) (in our case farm systems), with its diverse dynamics and influences is particularly challenging (Choptiany et al., 2016). Different resilience tools already exist focusing on different aspects and scales (Barron, Douxchamps, Debevec, Giordano, & Barron, 2017). One of the resilience measurement tools for an agricultural context was developed by the Food and Agriculture Organization of the United Nations (FAO); it is called the 'Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists' (SHARP[49]). The tool builds upon the IPCC definition of resilience (IPCC 2014): "the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation".

SHARP-based assessments aim at strengthening resilience through an approach built on flexibility, learning and the knowledge of farmers themselves (Choptiany, Phillips, Graeub, Colozza, & Dixon, 2015). It is both a quantitative and a qualitative measurement tool, since it considers the perceived and expressed needs of farmers. This is possible because it works on household level and on a participatory basis in close cooperation with the farmers (Choptiany et al., 2016). Information is generated and analyzed with the farmers on site. Inadequacy in understanding the local context often leads to the failure of agricultural extension services, especially in Africa (Isubikalu, 2007). To avoid this bias, the SHARP-tool was designed in a trans-disciplinary manner, including technical experts, academia, extension services and local farmers and works to empower agricultural producers to self-assess their resilience and provide direct inputs into the results (Choptiany et al., 2016). In the SHARP-approach, it is recommended that a facilitator supports the farmers in completing the SHARP survey and in disentangling their resilience scores. To strengthen farm system resilience, the emphasis is put in using

[49] See http://www.fao.org/in-action/sharp/en/

and building upon local knowledge. Since the first implementation of SHARP in 2013, the tool has been adapted to and used in over 18 different countries to assess, monitor and evaluate resilience (FAO 2018).

In Switzerland, the tool has been adapted with the help of local experts' knowledge, and feedback from farmers through a pilot study with 25 farmers (Diserens et al., 2018).

In this paper, the authors focus on a selection of relatable farming systems and the resulting resilience assessments, as well as overall key issues brought forth by the assessment tool and discussed with farmers during group workshops.

The research question explored in this article is thus, based on a case study around two oppositely diversified farming systems in Canton de Vaud: *RQ - How is resilience built differently between different farming systems in a same region?* Two hypotheses will be discussed. *H1: "The overall resilience is higher for more diversified farming systems"* and *H2: "Diversified farming systems tend to have a stronger focus on agroecological practices while more specialized farming systems may have a stronger focus on diversifying their selling channels".*

1. Canton Vaud context

Canton Vaud agriculture and challenges

Switzerland is divided in three main geographical areas: the Alps, the Swiss Plateau and the Jura (Fig 2.). Each region has a rather distinct climate and its own agroecological zone (AEZ). The Canton Vaud is situated in the South-West of the Switzerland and is a good representation of the Swiss geography as it embodies all three distinct regions described above. It encompasses high peaks and mountains rising up to 3,210 m, as well as plains and lakes at low altitudes (EDA online 2018).

In the plain region of the Canton ("plateau"), the cropping systems include staple crops, vegetable and fruit production as the climate in this region is particularly suitable for them with a long vegetation growing period and temperate rainfall. This is in contrast to the situation in the mountainous Jura and Alps regions, where the vegetation growing period is rather short, which allows for mainly pasture and animal production (AGRIDEA 2011, Schulz et al. 2018)). The dynamic between mountains and plains takes an important place. Nevertheless, field crops remain important for Vaud as more than half of the agricultural area is dedicated to them. Thus, Vaud has a really rich and diversified agriculture.

Figure 25: Map of Switzerland displaying the three main regions (green: Jura, yellow: Swiss Plateau cultivated mostly with open field crops and brown: Alps) and the borders of the Canton Vaud (in black). Adapted from Office Fédéral de l'environnement, 2008. Photo credit: U. Le Goff

In the context of economic instability and loss of attraction of agriculture, the number of farms has considerably decreased over the last 40 years dropping from 111,000 in 1975 to 51,600 in 2017. In parallel, the average area of these farms has almost doubled to reach 20 ha. In contrast, organic farming is increasing and now 14% of Swiss farms are organically certified (OFS, 2017). Organic farms are economically better off in terms of financial sustainability (Sanders et al., 2014; van der Ploeg et al., 2019). Like organic agriculture, other systems of production ("integrated production", very similar to integrated pest management) that are more environmentally sustainable are gaining importance on the domestic market. This diversification is opposed to the specialization promoted by policies and the need of doing structural economic changes to reduce cost in the past years (Knickel et al., 2018).

The Vaud agricultural policy promotes subsistence and quality agricultural production, which is environmentally sustainable and provides sufficient economic remuneration for the farmers (Blättler, 2016). The Vaud agriculture must meet the needs of the market and society as written in the agricultural policy (LAgr and RAgrEco 2010). Therefore, agriculture is in a delicate position, because it is subject to market uncertainties and economic constraints like price volatility and low competitiveness in comparison with other countries, as well as to the societal changes (pressure to reduce drastically chemical pesticides and fertilizers, increasing demand for organic and local food, etc.).

In Vaud, as in Switzerland overall, agriculture is facing major challenges. Climate change is becoming a significant issue for farmers along with other challenges that threaten the agricultural production and the economic stability of Swiss agriculture. These issues are notably the opening of the Swiss borders to international products and the increase in urbanization that could lead to great disturbances. In his report on Swiss French agriculture conducted in 2016 Blättler (2016) recommends to implement tools and measurement to address the growing uncertainties concerning agricultural prices and climate change. As a matter of fact, even in a wealthy country like Switzerland, agriculture can be highly affected by globalization and climate change. In 2018, the consequences of climate change were already seen in Vaud: the heavy drought has been especially detrimental to mountain pasture and rain-fed crops (e.g. vine, field crops and arboriculture) (USP online 2018). Emergency assistance was put in place to provide water for the cattle on the mountain pastures in conjunction with a decrease in border taxes on animal feed.

2. Tools and methods

Farm system resilience assessments

A set of 69 questions asked in face-to-face and remote surveys and related to the 13 behavior-based resilience indicators identified by Cabell & Oelofse (2012) have been taken as basis for the resilience assessment, together with their individual scores. The computation of the 13 indicators was conducted by merging the different SHARP question scores by following the methodological framework in (Choptiany et al., 2015). The 13 indicators integrate multiple aspects from different question areas to provide a comprehensive assessment of resilience.

Figure 26. The adaptive cycle and Cabell and Oelofse's 13 agroecosystem indicators

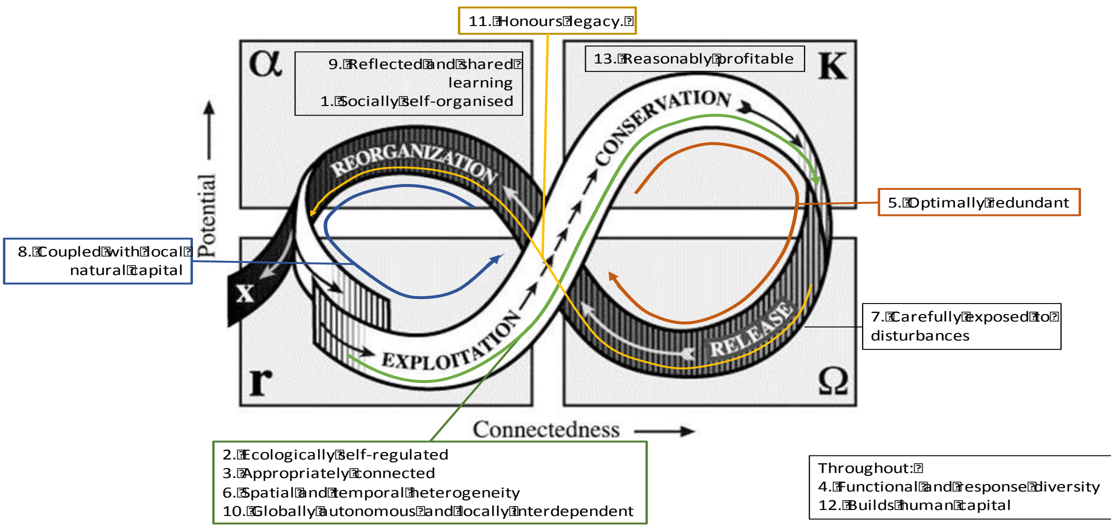


Table 1: Indicators along the adaptive circle

Adaptive cycle phase	Agro-ecosystem indicator	Features	Rating criteria* Switzerland
Release (Ω)	7: Exposed to disturbances	The system is exposed to discrete, low-level events that cause disruptions without pushing the system beyond a critical threshold	New varieties & breeds, crop & livestock losses, information/education, buffer zones, weed management, dealing with disturbances
Release (Ω) to Reorganization (α)	1: Socially self-organized	Farmers and consumers are able to organize into grassroots networks and institutions such as co-ops, farmer's markets, community sustainability associations and advisory networks	Group membership, crop & livestock losses, access to water, dealing with shocks, community cooperation, previous collective action, access to markets
	9: Reflective and shared learning	Individuals and institutions learn from past experiences and present experimentation to anticipate change and create desirable futures.	Household composition, record keeping, access to information, governmental policies, group membership, disturbances
	11: Honors legacy	Maintenance of heirloom seeds and engagement of elders, incorporation of traditional cultivation techniques with modern knowledge	Household composition, production forms, trees & agroforestry, information/education
Reorganization (α) to Exploitation (r)	8: Coupled with local natural capital	Builds (does not deplete) soil organic matter, recharges water, little need to import nutrients or export waste	Land management practices, livestock practices, trees & agroforestry, synthetic pesticides use, water conservation, water quality, soil quality, presence of legumes, energy conservation, fertilizer use
Exploitation (r) to Conservation (K)	2: Ecologically self-regulated	Self-regulated pest management (usage of predators or parasitoids), use of ecosystem engineers, and align production with local ecological parameters	Crop production, new varieties & breeds, trees & agroforestry, synthetic pesticides use, access to water, presence of legumes, buffer zones, energy sources, energy conservation, fertilizer use
	3: Appropriately connected	Collaborating with multiple suppliers, outlets, and fellow farmers; crops planted in polycultures that encourage symbiosis and mutualism	Seed & breed sources, access to information, intercropping, veterinary access, community cooperation, previous collective action, information & communication technologies, market information, market access (buying/ selling), price stability

	6: Spatial & temporal heterogeneity	Patchiness on the farm and across the landscape, mosaic pattern of managed and unmanaged land, diverse cultivation practices, crop rotation and in association	Crop production, trees & agroforestry, intercropping, land ownership, soil quality and soil management
	10: Globally autonomous & locally interdependent	Less dependence on commodity markets and reduced external inputs; more sales to local markets, reliance on local resources; existence of farmer co-ops, close relationships between producer and consumer, and shared resources	Livestock nutrition, new varieties & breeds, animal diseases, land ownership, energy sources, weed management, collective action, local farm input, direct marketing, market access (buying)
	13: Reasonable profitable	Farmers and farm workers earn a livable wage; agriculture sector does not rely on distortionary subsidies	Productive assets, insurances, main income sources, external income, savings, investments, financial resources, stakeholder interactions, market access (buying)
Conservation (K) to Release (Ω)	5: Optimally redundant	Planting multiple varieties of crops rather than one, keeping equipment for various crops, getting nutrients from multiple sources, capturing water from multiple sources	Crops, livestock nutrition & practices, new varieties & breeds, trees & agroforestry, access to water, land management, energy sources, fertilizer use, group membership, productive assets, market access (buying & selling)
Throughout the Cycle	4: Functional & response diversity	Heterogeneity of features within the landscape and on the farm; diversity of inputs, outputs, income sources, markets, pest controls, etc.	Production types, aquaculture, crop and livestock practices, trees & agroforestry, animal diseases, pest management, buffer zones, weed management, main income sources, market access (buying & selling)
	12: Builds human capital	Investment in infrastructure and institutions for the education of children and adults, support for social events in farming communities, programs for preservation of local knowledge	Household composition, infrastructure, synthetic pesticides, water quality, land management, legumes, buffer zones, fertilizer, group membership, food

Representative sampling through a k-medoids clustering

Due to its diversity of environments and agricultural productions, the Canton Vaud presents a wide range of farming systems. Capturing this diversity through a typology is crucial for understanding the farming system. (Dixon, Gulliver, & Gibbon, 2001; Kuivanen et al., 2016). We thus aimed at simplifying this complexity by identifying a small number of farming systems (<20), i.e. structurally similar farms in terms of productions and size so that we could get insight on resilience for each of these farming systems.

Farm systems are a part of a complex network of social and ecological interactions comprised of environmental, economic, social and political factors (Ikerd, 1993; Moller, Darnhofer, & Fairweather, 2008), and can be considered as a SES (Ostrom, 2009). A farming system (FS) is comprised of multiple, individual farms with similar resources, production patterns and external conditions (Darnhofer, Gibbon, & Dedieu, 2012; Dixon et al., 2001). It must be mentioned, that for this paper, the farms in each farming system are grouped according to their productive surfaces and livestock and may show large variations, e.g. the production patterns or the resource bases vary among FSs. Nevertheless, farms were grouped into FSs, under the hypothesis that FS' complexity may be the most decisive factor for measuring resilience (Bennett, Cumming, & Peterson, 2005; Carpenter, Bennett, & Peterson, 2006; Darnhofer, 2010).

The identification of FS was carried out using the Vaud Acorda® public dataset from 2016. This dataset is collected annually to register all surfaces cultivated by farmers as well as livestock in order to direct government subsidies. It comprises more than 150 variables for 3,284 farmers (as of 2016). Unregistered farms were thus ignored from this study; these correspond to a few large agricultural wine and pork companies integrating the whole value chain and numerous small producers doing this often as a hobby (*e.g.* <1,000m² of vine). Preliminary work was carried out to group variables according to similarities in terms of technical-economic impacts on the farm. This work was carried using local literature and local expert interviews (administration, extension services, farmers, etc.). 14 surface items and 6 animal items resulted from this preliminary work. Some variables were kept as informative variables.

Based on this data, a cluster analysis was carried on all 20 variables and 3,184 farms to group farms in FSs. We conducted this using a k-medoids clustering algorithm using the R software program. The process for determining k (the number of clusters) was a back-and-forth discussion with experts and analysis of resulting clusters. Although our first aim was to reach a k between 10 and 15 to make it easier to present and use, we had to go up to 22 different clusters due to the wide diversity of situations existing in the Canton, which local experts considered an accurate representation of the diversity of farming systems in the Canton.

Table 17: Cluster analysis results in 22 FS

FS number	Name given (based on a post-clustering analysis)	Interviewed	Amount of farms comprised
1	Small-size pasture-based livestock farm	8	397
2	Mid-size crop pasture-based livestock farm	19	343
3	Mid-size cereal growers	8	303
4	Dairy farms with large herds	8	289
5	Mid-size cereal and beet growers	5	244
6	Small-size vineyards	6	228
7	Above average-scale cereal farms	5	178
8	Meat cattle farms	4	174
9	Permanent grassland farms	5	173

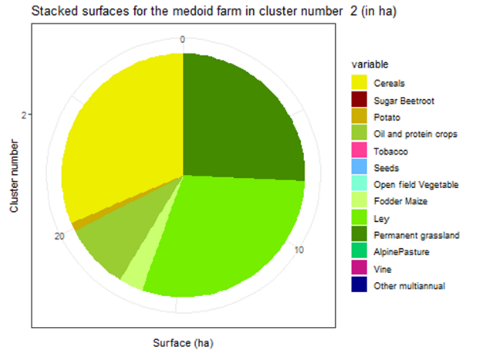
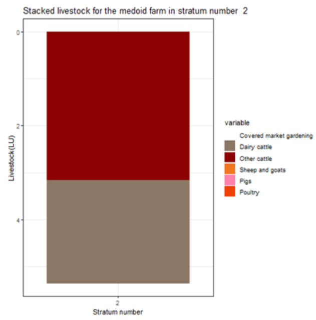
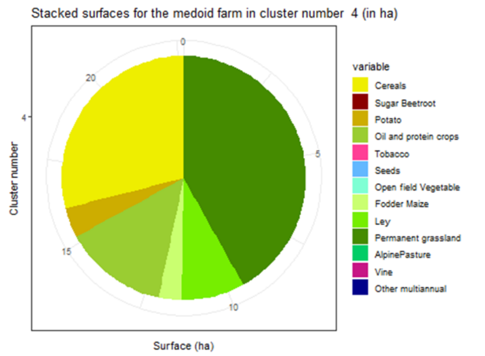
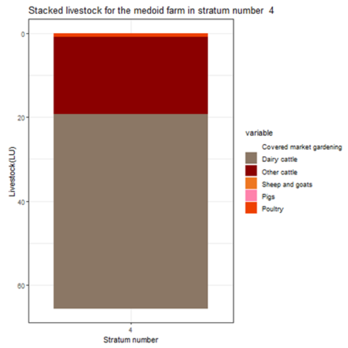
10	Large beet and cereal farms	6	151
11	Fodder producers	5	133
12	Large pasture-based dairy farms with limited livestock	4	114
13	Transhumant dairy farms	5	99
14	Beet and potato farms	6	95
15	Large vineyards	1	90
16	Horse farms	5	76
17	Poultry farms with limited surface	7	58
18	Seeds and cereals farms	6	54
19	Tobacco farms	5	34
20	Sheep and goat farms	4	25
21	Fruit tree farms	0	16
22	Pig farms	0	10

Choice of farming systems for comparison

The focus in this paper is on two typical farming systems in the Canton, corresponding to the second and fourth most numerous clusters (343 and 289 farms) resulting from the cluster analysis. Since the FSs were created based on the surface areas and livestock units, and centered around existing farms (*medoids*), they may sensibly be described by the corresponding values for the medoid farms. The two FSs use roughly the same land area (around 25-30 ha) in a similar way (>50% pastures) but a major difference lies in the degree of specialization in dairy production; farms included in FS2 usually include cattle but to a rather low level (<6 LU in the medoid farm) while FS4 is characterized by a relatively large dairy cattle herd (>60LU for the medoid farm), which is the highest medoid value among all FS. This difference can be expected to have major impacts on the resilience of both FSs as it may reveal major differences in the strategy used by farmers in both cases to reach their own objectives. Farms in FS2 can be expected to meke use of extra activities to maintain sufficient revenues (direct selling, part-time job outside the farm, etc.) while the FS4 may have focused on decreasing marginal costs through investing in larger facilities.

The choice of FSs analysed here is motivated first by frequent and recent droughts in Switzerland (notably 2015 and 2018) during summer. These can have largely affected grassland productivity (Meisser et al., 2013) and cattle owners, although emergency measures from the Canton helped reduce the impact. This choice is also motivated by the recurring difficulties encountered by the dairy producers in Switzerland to reach decent revenues from milk, especially for those selling to industrial processers outside of the Protected Designation of Origin (PDO) productions.

Figure 27: Medoid farms UAA and LU distribution for FS2 and FS4

<table>
<tr><th>Medoid farms (2016)</th><th>Utilised Agriculture Area distribution</th><th>Livestock Units distribution</th></tr>
<tr><td>FS 2</td><td>
</td><td>
</td></tr>
<tr><td>FS4</td><td>
</td><td>
</td></tr>
</table>

Although FS4 from this data may seem to be more diversified, as it includes more cattle for an overall similar set of crop and grassland productions, we here consider it to be the more specialized one. Indeed, most of the production from grassland and crops in FS4 are likely to be destined for cattle feed and milk production may eventually be overwhelming over other outputs.

Farmers from both farming systems were interviewed within the project (19 from FS2 and 8 from FS4).

Discussion workshops

Discussion workshops were held to help address the issues identified with the lowest resilience scores in each region. In each case, the 5 or 6 least resilient aspects at the regional level were proposed for the group discussion. As a reminder, the importance scores were also presented. Where possible, only the scores corresponding to the participants in the discussion session were taken into account. Collectively, 3 aspects were chosen each time, on which each participant could contribute to explain the causes of these relatively low scores of resilience and develop possible solutions to improve the situation.

3. Results

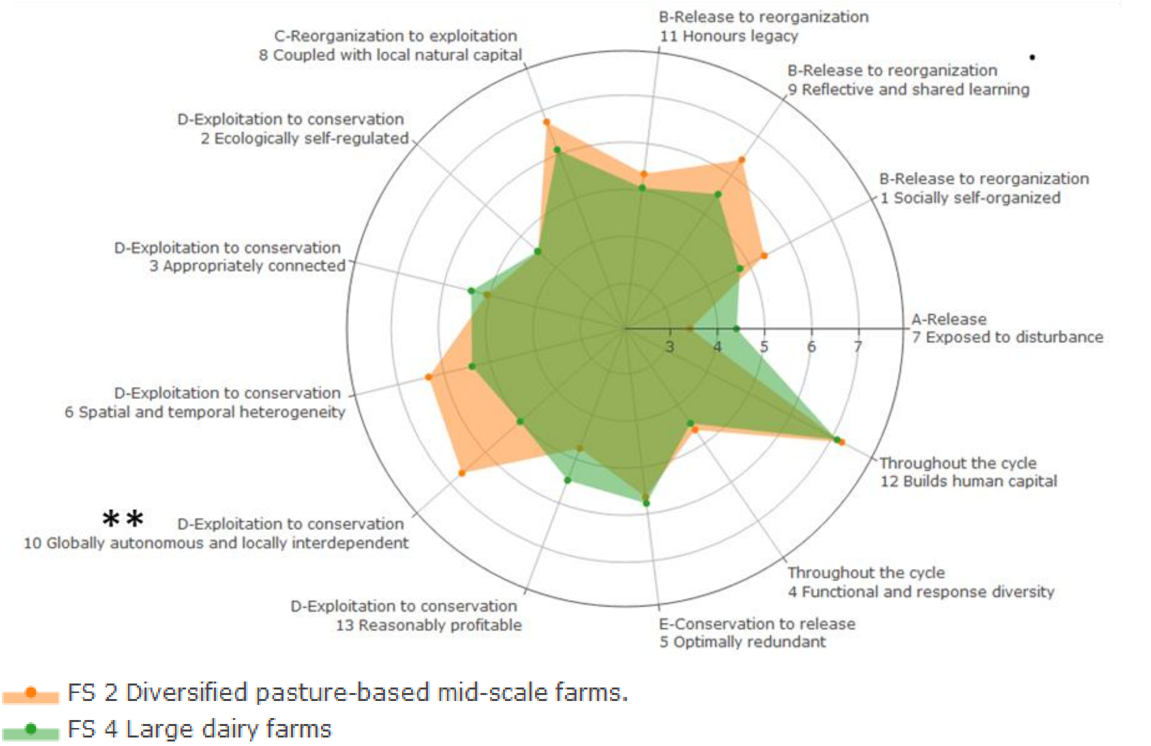
Resilience assessments

Average values for most resilience indicators differ between FS2 and FS4 but disparities within each FS complicate the analysis of significant differences. Analyses of variance were carried for each indicator, revealing only one indicator with significant different values: *10 - Globally autonomous and locally interdependent*. (see Figure 4 below). This indicates that large dairy farms (represented by FS4) are more dependent on global trends than less specialized farms (represented by FS2), which have a closer connection with their local socio-economic environment. This is particularly crucial in Switzerland where further opening of the national agri-food market to foreign production is a recurring debate, as it puts many farmers producing standard products for the food industry at risk.

As discussion workshops revealed, this risk was precisely perceived as higher than the one related to climate change. Indeed, many farmers are so far not sure about future impact of climate change on Swiss agriculture. They feel much more at risk when it comes to decrease or volatility of the prices paid for agricultural commodities.

Thus, the relative difference observed between both farming system for this indicator means a much secure situation for less specialized farmers involved in more than one supply chain and less dependent on external factors. This degree of control on their situation can also be a factor of satisfaction (Sumarwan & Hira, 1993).

Figure 28: Resilience indicators for farming systems FS 2 - Diversified pasture-based mid-size FS and FS 4 - Large dairy FS. The scoring ranges from 0 to 10 and was here zoomed from 2 to 8 to better visualize existing differences.



The general situation across the two farming systems can also be drawn from these results. We observe strengths over indicators related to learning, knowledge transmission and education (indicators 9, 11 and 12), indicating a good learning process over generations. However, the observed relative lack of positive connections among local actors may somehow prevent peer to peer learning (indicators 1, 3 and to a varying degree indicator 10).

The degree of exposure to disturbance is possibly too high in Switzerland, as shown by indicator 7. This could be due to a combination of a relatively high use of pesticides, high prices and price control for certain commodities compared to neighboring countries, and especially for Protected Designation of Origin (like Le Gruyère PDO), efficient public support in case of critical situations (for ex. severe droughts), and high level of insurance coverage. While this situation is currently comfortable, it blocks certain adaptations, as well as the learning process to adapt to shocks. Such high combination of public support and private insurance protection can be analyzed as provoking a lack of stimulation to adapt, and a less developed capacity to react to shocks when they occur. This provokes structural rigidities and anxiety by the farmers, who develop as well defensive attitudes towards changes.

Aside from the differences observed at the indicator level, the relative proximity for most indicators at the indicator level between the two FSs indicates the rather small impact of the nature and amount of the crops grown and livestock owned on the farm resilience. Elements assessed through the SHARP tool include questions about the way the land is managed and how the animals are bred (agronomic and zootechnical factors), the way production is valued and sold in and from the farm (economic factors), as well as more social factors like the education, the groups in which farmers are, etc. Thus, this study reveals that the choices made at technical level (crops, livestock) is not much correlated with the various resilience scores. The conclusion is that other communalities are more likely to play an important role, notably the agricultural policy, and the economic situation.

Based on these results, the hypothesis H1 (*The overall resilience is higher for more diversified farming systems.)* could be confirmed. However, H2 (*Diversified farming systems tend to have a stronger focus on agroecological practices while more specialised farming systems may have a stronger focus on diversifying their selling channels.)* could not be confirmed. It rather seems in this case that their high level of production in one type of output constrains them to sell to a larger intermediary processer and prevents them from reaching to other selling channels for which a diversity of production may be preferential.

Discussion workshops

Several aspects of the farm systems were discussed during the discussion workshops-The aspects discussed were: policies and standards, savings, sales prices, market access, short circuits, past collective actions, energy conservation, water conservation, ecological buffer zones, management of pests, loss of crops and livestock, associated crops and trees and agroforestry.

For each aspect discussed, the regions in which these aspects were discussed are mentioned as well as the causes and identified solutions. The ideas are reported as advanced by the participating farmers and do not necessarily reflect the views of the partners and collaborators involved in this project.

As examples, we present here the discussion of four important topics: “Policies and standards”, “Conservation of energy”, “Water conservation” and “Mixed cropping and agroforestry”.

Policies and standards were discussed in all regions: Broye, Jura, Chablais, Morges, Pays d'Enhaut. This was actually the most discussed aspect in the 5 workshops. Farmers shared their general weariness with the current system, which they believe is too restrictive and changing. The lack of consideration of local situations has also been mentioned several times, as well as the heavy administrative burden. This set makes innovative take-up difficult for most operators. The gap between the agricultural world and the rest of society and the economy has also been identified as a major fragility. Participating farmers expressed that they would like a more regionalized and stable agricultural policy. Peasant solidarity and the common defense of the rights and interests of the profession are mentioned as important elements to ensure the establishment of a satisfactory agricultural policy. Contact and communication with the rest of society are also presented as a way of freeing themselves from distorted or truncated visions of the agricultural world that are sometimes widely disseminated.

Conservation of energy was discussed in 4 regions: Chablais, Broye, Morges, Pays d'Enhaut.

The lack of energy-efficient infrastructure was notably explained by (1) the level of needed investment, (2) the sometimes heavy administrative and regulatory constraints (eg. Lavaux in the UNESCO heritage zone), (3) the lack of profitability due to the relatively too small size of farms (for example for biogas plants) and the current much too low price of energy. In order to allow for greater development of energy savings or autonomy, farmers asked for the simplification of procedures, the organization of collective networks and the promotion of small-scale solutions (such as chip boilers or old fans). Synergies between energy policy and agricultural policy should favor such a development.

Water conservation was a topic in 4 regions: Jura, Plain of the Orbe, Broye. The great variability of climatic situations between years and during each year, probably related to climate change, was found to explain the difficulty of conserving water over a year. The infrastructures were declared insufficient and often not sufficiently maintained. Increasing concreting of the landscape could also explain the instability of the water supply. Farmers advocated for more water-retaining structures to better spread water access over the year and less water-intensive farming practices such as conservation agriculture, under-seeding or the use of sheep in the vineyard to manage the grass.

Mixed cropping and agroforestry topics were discussed in three different workshops (Regions Plain of the Orbe, Morges, Nyon). The mentioned causes of a relatively weak development of these practices were (1) the level of technicality that requires time and motivation to learn, (2) the external gaze of passers-by and neighbors on visibly heterogeneous or even "dirty" plots, (3) advice provided by phytosanitary selling companies that does not always favor these practices and (4) the lack of outlets for productions resulting from these practices. For agroforestry, the participants also mentioned the complexity and the administrative rigidity, in particular at the level of zoning, as well as the need for a long-term vision to make the investment profitable over several decades, which is complicated by transmission difficulties and uncertainties at this time scale. The development of these practices therefore, according to the participants, depends on more popularization and sharing of knowledge. The participants advocated solutions to support collective agreement in order to develop adequate ways of selling the products, for ex. the establishment of agreements with mills to sort mixed crops for associated crops or self-harvesting for agroforestry. Specific material could be purchased collectively.

4. Discussion and conclusion

This study confirmed the high diversity of FSs in Canton Vaud in Switzerland. It allows a broad understanding of different farm dynamics and regional issues affecting agriculture. This diversity of productions is nevertheless tempered in terms of resilience by a rather constraining and protected context, notably due to the Swiss agricultural and commercial policies.

A limit of our approach is the small sample size per farming systems, and the scoring benchmarks used in the SHARP tool in its Swiss version, which may rather highlight all the range of possible answers instead of highlighting results when existing.

The results show that the nature of cultivated crops and the herd size (used to construct the FSs here) may not be the most relevant factors for farm system resilience, as how crops are grown and how products are sold may matter as much.

In order to understand territorial dynamics affecting farming systems and their interactions in a changing environment, there is a need for methodologies of resilience assessments suited to a diversified territory including a broad range of FSs, and not solely to specific supply chains. We believe this study paves the way forward to reach this. The greater data availability linked to the digitization of agriculture is also promising to improve the type of data collected and used for the assessment.

The SHARP approach and tool proved to be useful to reach insightful regional and farmer-based perspectives on resilience development, by evaluating individually and discussing collectively the situation and the underlying issues and opportunities. These results should however not be mistaken for sustainability assessments. Assessing resilience allows concluding on adaptation and mitigation strategies, and reasons behind adopting a proactive behavior in building more resilient FSs. Further investigation should be carried on the FS dynamics (growth, specialization, diversification, etc.) and the reasons mentioned by farmers for these changes. In our case study, this may be done in the future by further exploring farm level data over different time periods.

Although the overall context seems, from these results, to play an important role on the farm resilience, this aspect was further discussed in a meta-analysis jointly carried together with staff from the FAO by comparing our results to those of another case study in Uganda using the SHARP tool in an adapted version (Le Goff et al., 2018). This study concluded that context indeed plays a major role in resilience, with highly adverse conditions possibly favoring the use of agroecological practices and locally grounded solutions. This study further highlighted the difference existing between resilience and sustainability and the need for both approaches to support development.

In the aftermath of the project, the cantonal and federal agricultural policy responded to the concerns expressed by farmers during our discussion workshops by funding a pilot and monitored agricultural policy around agroforestry for 2020-2028 in order to better understand its actual impact in Switzerland before possibly implementing it in a future federal agricultural policy.

References

Agridea, (2011). Valorisation des produits des filières agricoles vaudoises. Rapport final. Lausanne

Barron, J., Douxchamps, S., Debevec, L., Giordano, M., & Barron, J. (2017). Monitoring and evaluation of climate resilience for agricultural development – A review of currently available tools Monitoring and evaluation of climate resilience for agricultural development – A review of currently available tools. *World Development Perspectives*, *5*(March), 10–23. https://doi.org/10.1016/j.wdp.2017.02.001

Bennett, E. M., Cumming, G. S., & Peterson, G. D. (2005). A systems model approach to determining resilience surrogates for case studies. *Ecosystems*. https://doi.org/10.1007/s10021-005-0141-3

Blättler, T. (2016). *Étude sur l ' agriculture romande*.

Carpenter, S. R., Bennett, E. M., & Peterson, G. D. (2006). Scenarios for ecosystem services: An overview. *Ecology and Society*. https://doi.org/10.5751/ES-01610-110129

Choptiany, J. M. H., Phillips, S., Graeub, B. E., Colozza, D., & Dixon, J. (2015). Self-Evaluation and Holistic Assessment of Climate Resilience of Farmers and Pastoralists. Retrieved from http://www.fao.org/3/a-i4495e.pdf

Choptiany, J. M. H., Phillips, S., Graeub, B. E., Colozza, D., Settle, W., Herren, B., & Batello, C. (2016). SHARP : Integrating a traditional survey with participatory self- evaluation and learning for climate change resilience assessment. *Climate and Development*, *9*(May 2016), 1–37. https://doi.org/10.1080/17565529.2016.1174661

Darnhofer, I. (2010). Strategies of family farms to strengthen their resilience. *Environmental Policy and Governance*. https://doi.org/10.1002/eet.547

Darnhofer, I. (2014). Resilience and why it matters for farm management. *European Review of Agricultural Economics*, *41*(3), 461–484. https://doi.org/10.1093/erae/jbu012

Darnhofer, I., Fairweather, J., & Moller, H. (2010). Assessing a farm's sustainability: Insights from resilience thinking. *International Journal of Agricultural Sustainability*, *8*(3), 186–198. https://doi.org/10.3763/ijas.2010.0480

Darnhofer, I., Gibbon, D., & Dedieu, B. (2012). Farming systems research into the 21st century: The new dynamic. *Farming Systems Research into the 21st Century: The New Dynamic*, (May 2014), 1–490. https://doi.org/10.1007/978-94-007-4503-2

Diserens, F., Choptiany, J. M. H., Barjolle, D., Graeub, B., Durand, C., & Six, J. (2018). Resilience assessment of Swiss farming systems: Piloting the SHARP-tool in Vaud. *Sustainability (Switzerland)*, *10*(12). https://doi.org/10.3390/su10124435

Dixon, J., Gulliver, A., & Gibbon, D. (2001). Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World. In *FAO, Rome; World Bank, Washington, D.C.*

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockstrom, J. (2010). Resilience Thinking: Integrating Resilience, Adaptability and Transformability. *Ecology and Society*, *15*(4).

Hoegh - Guldberg O, D, J., M, T., M, B., S, B., I, C., … Zhou, G. (2018). Chapter 3: Impacts of 1.5°C global warming on natural and human systems. *Global Warming of 1.5 °C an IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change*.

Ikerd, J. E. (1993). The need for a system approach to sustainable agriculture. *Agriculture, Ecosystems & Environment*, *46*(1), 147–160. https://doi.org/https://doi.org/10.1016/0167-8809(93)90020-P

Isubikalu, P. (2007). *Stepping-stones to Improve Upon Functioning of Participatory Agricultural Extension Programmes: Farmer Field Schools in Uganda*. Retrieved from http://books.google.com/books?hl=en&lr=&id=OsaUVp_mLHMC&pgis=1

Knickel, K., Redman, M., Darnhofer, I., Ashkenazy, A., Calvão Chebach, T., Šūmane, S., … Rogge, E. (2018). Between aspirations and reality: Making farming, food systems and rural areas more resilient, sustainable and equitable. *Journal of Rural Studies*, *59*, 197–210. https://doi.org/10.1016/j.jrurstud.2017.04.012

Kuivanen, K. S., Alvarez, S., Michalscheck, M., Adjei-Nsiah, S., Descheemaeker, K., Mellon-Bedi, S., & Groot, J. C. J. (2016). Characterising the diversity of smallholder farming systems and their constraints and opportunities for innovation: A case study from the Northern Region, Ghana. *NJAS - Wageningen Journal of Life Sciences*, *78*, 153–166. https://doi.org/10.1016/j.njas.2016.04.003

Meisser, M., Deléglise, C., Mosimann, E., Signarbieux, C., Mills, R., Schlegel, P., … Jeangros, B. (2013). Effets d’une sécheresse estivale sévère sur une prairie permanente de montagne du Jura. *Recherche Agronomique Suisse*, *4*(11–12), 476–483.

Moller, H., Darnhofer, I., & Fairweather, J. R. (2008). *Farm resilience for sustainable food production: a conceptual framework*.

OFS. (2017). *Landwirtschaftliche Strukturerhebung Relevé des structures agricoles 2017*.

Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science*, *325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Schulz, T., Lauber, S., & Herzog, F. (2018). *Summer Farms in Switzerland : Profitability and Public Financial Support Summer Farms in Switzerland : Profitability and Public Financial Support*. (October). https://doi.org/10.1659/mrd-journal-d-16-00118.1

Sumarwan, U., & Hira, T. K. (1993). The effects of perceived locus of control and perceived income adequacy on satisfaction with financial status of rural households. *Journal of Family and Economic Issues*, *14*(4), 343–364. https://doi.org/10.1007/BF01013984

Tendall, D. M., Joerin, J., Kopainsky, B., Edwards, P., Shreck, A., Le, Q. B., … Six, J. (2015). Food system resilience: Defining the concept. *Global Food Security*, *6*, 17–23. https://doi.org/10.1016/j.gfs.2015.08.001

van der Ploeg, J. D., Barjolle, D., Bruil, J., Brunori, G., Costa Madureira, L. M., Dessein, J., … Wezel, A. (2019). The economic potential of agroecology: Empirical evidence from Europe. *Journal of Rural Studies*, *71*(December 2018), 46–61. https://doi.org/10.1016/j.jrurstud.2019.09.003

Walker, B., Hollin, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society*, *9*(2).

IPCC (2014). Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press United Kindom and New York, NY.

FAO & GEF (2018). Project document: Integrating climate resilience into agricultural and pastoral production in Uganda, through a Farmer/Agro-pastoralist Field School Approach. Unpublished document.

EDA, (2018). Découvrir la Suisse. https://www.eda.admin.ch/aboutswitzerland/en/home/umwelt/geografie.html. Last accessed 17.10.19

Sanders, J., Nieberg, H., Offermann, F., (2014). Is organic farming still financially attractive in Switzerland? (Non published)

Règlement sur l’agroécologie (RAgrEco), (2010). Canton de Vaud

Union Suisse des Paysans (USP), (2018). Rapport sur la situation de l’agriculture suisse - septembre 2018.

Le Goff, U., Sander, A., Hernandez Lagana, M., Phillips, S., Monnier, A., Savino, L., Barjolle, D., Six, J. *Assessing farm system resilience: an indicator- based approach in Switzerland and Uganda.* Resilience Measurement: *Evidence and Learning*; 2018 Nov 12-15; New Orleans, U.S.A.

ASSESSMENT OF VULNERABILITY TO CLIMATE CHANGE OF MAIZE FARMING SYSTEMS: DESIGNING AN INDICATOR SET BASED ON FARMERS' PERCEPTIONS AND KNOWLEDGE

Marine Albert, Jacques-Eric Bergez, Stéphane Couture

INRAE, France

Abstract: Maize growers in Southwestern France are facing increasing climatic variability, creating negative impacts on their farming systems (e.g soil erosion, water stress). Understanding vulnerability of these farming systems is an essential step in order to enhance new adapted farming systems toward climate change. Although vulnerability is a central concept in climate change studies (IPCC, 2021), and has already been discussed a lot in the literature (Martin et al., 2017), there is scarce knowledge on its operationalization to assess farming systems (Callo-Concha and Ewert, 2014; Urruty et al., 2016). This thesis aims at contributing to this issue by identifying determinants of vulnerability and create a generic multicriteria methodology to assess vulnerability at farm level. Surveys with maize growers are central in our work, since we build a set of indicators based on farmers' perceptions and knowledge. Original methods are used in order to elicite determinants of vulnerability, such as lottery games, role plays, and scenarii. At this stage of the thesis, results revealed (i) the important influence of cognitive and psychological factors of the farmer on vulnerability of the farming system, and (ii) a significative heterogeneity among farmers in their evaluation of adaptation strategies for reducing vulnerability. We plan to confront the set of indicators based on farmers to literature and experts in order to develop and validate the set of indicators as well as its operational framework, from a scientific point of view. To this end we will use participatory methods through focus groups involving both researchers, agronomists and technical advisors. Finally we will test the revised set of indicators with maize growers to make sure of its suitability and good handling. Results of this thesis will give knowledge and tools for advisors and policy-makers to adapt their support strategies for maize growers, in a context of climate change.

CAN WE PUSH AGROECOLOGY A STEP FURTHER?

Sara BURBI[a], Ulrich SCHMUTZ[b] and Stéphane BELLON[c]

[a] Centre for Agroecology, Water and Resilience (CAWR), Coventry University, United Kingdom
[b] Centre for Agroecology, Water and Resilience (CAWR), Coventry University, United Kingdom
[c] French National Institute for Agricultural Research (INRA), Department of Sciences for Action and Development, Avignon, France

Abstract: There have been many studies recently advocating for the adoption of more agroecological farming practices related to climate change. In this session we want to go beyond the initial concepts of agroecology and address specific needs such as reduced dependence on external inputs. We feel, while agroecology can be well received as a theoretical concept by practitioners in a wide range of contexts, there is a need to delve deeper into its practical and technological aspects to implementing it further. We are looking for works that takes agroecology a step further. For example, farming system solutions for Mediterranean horticulture with zero pesticides inputs (also including zero copper or mineral oils - still allowed in certified organic farming) can be a challenge to implement and may need innovative approaches. Another example can be silvopastoral systems the production of tree fodder with anti-parasitic and anti-microbial effects, eliminating synthetic drugs use in animal husbandry. Similarly, the use of plastics is still wide-spread and phasing out other climate change relevant inputs like peat has still not taken off, especially in horticulture. Food storage and processing can also be an asset in alleviating impacts of climate change. Moreover, technological pathways exemplifying how changed agroecological food and farming systems can contribute to climate-friendly designs are welcome. These may include a reduction in use of external inputs during the production phase, dietary changes and pasture management strategies to reduce emissions from livestock, storage, treatment and application technologies to mitigate emissions from manure. The potential consequences of changed practices and inputs on the adaptation and mitigation of climate change are important to assess, together with their integration into short food supply chains and changed diets.

CARBON FOOTPRINT OF IBERIAN DEHESA PRODUCTS: SEQUESTRATION IN SOILS AND WOODY VEGETATION CAN OFFSET LIVESTOCK EMISSIONS.

Mireia Llorente[a], Gerardo Moreno[b]

[a] Forestry School, University of Extremadura, Plasencia, Spain
[b] INDEHESA, Forestry School, University of Extremadura, Spain

Abstract

The Iberian dehesa is a traditional, but also up-to-date, Mediterranean agrosilvopastoral system. It might be regarded as a successful example of how a farming system can be compatible with resource conservation and sustainable development, while also playing an interesting role in Climate Change mitigation. Carbon from the atmosphere is fixed by plant photosynthesis and stored as carbon in aboveground and belowground biomass. Soil organic matter also represents a great sink of C. In parallel, greenhouse gas emissions from livestock production systems are usually considered to be the largest source of agricultural emissions. There is a knowledge gap regarding to what extent carbon sequestration in the ecosystem can offset emissions in extensive silvopastoral systems. The link between Climate Change and livestock farming has made the Carbon Footprint a worldwide indicator for assessing and communicating the amount of greenhouse gases emitted per unit of product. Nevertheless, most studies do not include soil and biomass carbon sequestration in their carbon footprint calculations. In this study, we point out the importance of noting that extensive farming is closely linked to dehesa ecosystem conservation and, therefore, the carbon footprint in pastoral systems should take geographical location into account.

We measured soil C stock changes at 110 points of the Iberian dehesa over a mean period of 22 years. We found temporal changes in soil C concentration ranging from -0.055 to 0.199% per year, with a SOC stock change average of 0.83 $Tn{\cdot}ha^{-1}{\cdot}year^{-1}$. That amount represents an annual soil C stock growth rate of around 11‰, way above the proposed '4 per mille Soils for Food Security and Climate' of the Lima-Paris Action Agenda. Aboveground biomass stock changes of trees were also measured by comparing the Spanish National Forest Inventories. The C sequestration rate in the trees amounts to 0.08 Ton $C{\cdot}ha^{-1}{\cdot}year^{-1}$. Taking into account soils and vegetation, C sequestration in dehesas would offset most of the emissions of GHG estimated for the livestock-based food produced in the pastoral farming system, including on- and off-farm emissions.

INTRODUCTION

Dehesas are agroforestry systems characterized by scattered trees among pastures, crops and/or fallows. Dehesas are traditional, but also up-to-date, agrosilvopastoral ecosystems of the Iberian Peninsula, which are adapted to the unpredictability of the Mediterranean climate (Joffre et al. 1999; Moreno and Cubera 2008). These multipurpose systems cover at least 4 million hectares in central and south-western Spain (Moreno and Pulido 2008). Extensive livestock systems are largely responsible for the ecological features of the dehesa. Livestock take advantage of the forage resources, not just comprising grassland, but also trees, which are used, not only as a resource in their own right, but also as a regulator of hydrological stress for the underlying herbaceous stratum (Joffre et al., 1999). Thanks to a reduced stocking rate, a balance can be achieved between animal pressure and the conservation of the territory.

The significant contribution of food production to greenhouse gas (GHG) emissions (Herrero et al., 2013) has made calculating the Carbon Footprint (CF) of food products increasingly popular. In that sense, it is important to note that extensive farming is closely linked to ecosystem conservation and, therefore, the CF in agroforestry systems should take geographical location into account. Carbon sequestration (C) in agroforestry systems must slow or even reverse the increase in atmospheric concentration of CO_2 by storing soil organic carbon (SOC) for millennia (Lorenz and Lal, 2014; Waldrom et al., 2017). However, there is a knowledge gap regarding to what extent C sequestration in the ecosystem can offset emissions in extensive silvopastoral systems, and usually no - or only generic - information on C sequestration rates is included in CF calculations.

Agroforestry systems are able to store significant quantities of C in biomass and soils. On the one hand, the largest terrestrial pool of C is found in soils, with spatially variable but large annual C exchanges with the atmosphere. Moreover, SOC is the major determinant of soil quality, and it greatly influences the global carbon cycle and climate change. Restoring, increasing and protecting SOC is, therefore, a global priority and is covered by the United Nations Conventions on Climate Change, Desertification and Biodiversity (Cowie et al., 2011). The SOC pool, in particular, is the only terrestrial pool with the ability to store carbon for millennia, and that ability can be deliberately enhanced by agroforestry practices (Lorenz and Lal, 2014). Therefore, dehesas would play an important role in the mitigation of global climate change through soil and vegetation conservation and management. However, the spatial heterogeneity of dehesas, their complex management and their generally low soil organic carbon contents (Howlett et al., 2011; Rodeghiero et al., 2011) may be the reason for the scant attention paid to that ecosystem. Determining the C storage capacity of this expansive land use in Spain will be vital to national C accounting, and may serve to foment the restoration of this and other savanna-like systems in the world.

On the other hand, vegetation C stocks and sequestration rates are both an important compartment in the C cycle and a relevant factor in soil C stocks, although the incorporation of biomass vegetation C stock and its C sequestration rates into CF of agroforestry products is scarce (Ruiz-Peinado et al., 2013). The rate of tree growth and timber harvesting determines the C storage capacity of living biomass and deadwood. Data from the Second and Third Spanish National Forest Inventories, which reflect changes over 10 years, is a useful tool for estimating the C storage in the tree biomass of dehesa systems and also the change rate in the C stock. The belowground biomass of forest landscapes plays a key role in carbon storage (Litton and Giardina, 2008). Since estimating belowground biomass is a complex process which requires great effort in terms of the time and cost of collecting data, a plausible approach to investigating forest belowground biomass is to establish a relationship between a number of dendrometric parameters related to the aboveground vegetation (e.g., tree diameter and height) and the belowground component of the total biomass (Ruiz-Peinado et al., 2012).

This study was undertaken to: (1) quantify C stocks in soils and tree biomass of Iberian dehesa systems; (2) estimate the C sequestration rate of the ecosystem by calculating C stock change rate; (3) establish the C sequestration potential of the dehesa following the concept of C saturation and soil C saturation deficit; (4) balance the C sequestration capacity of the dehesa and GHG with its extensive livestock systems.

MATERIAL AND METHODS

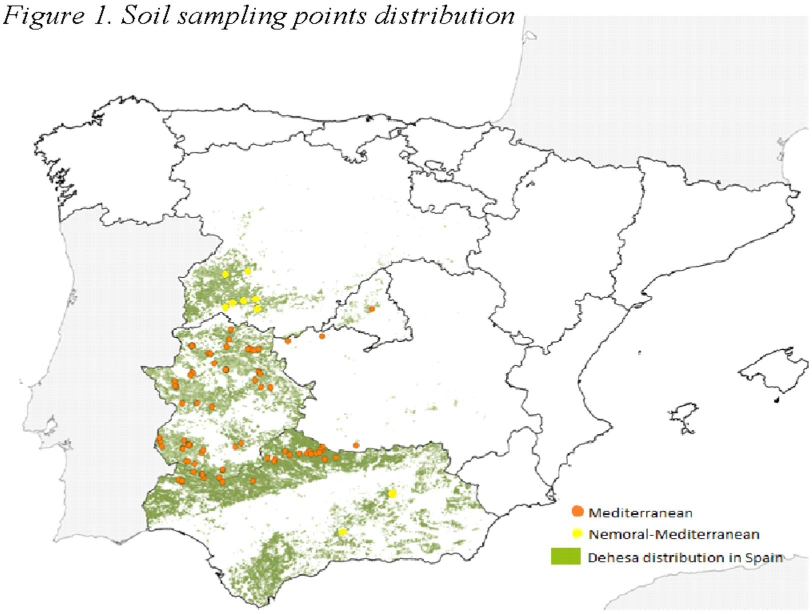
Site Description

The Mediterranean dehesas are between 350 and 550 m.a.s.l. The climate is typically Mediterranean, with high climatic intra- and inter-annual variability. Rainfall, from 400 to 800 mm, is concentrated during the cooler months of the year and there is a long period of summer drought, with high temperatures and without relevant rainfall. The mean annual temperature ranges from 14 to 17^{o}C. During periods of dry and sunny weather, between June and September, plant-available water is quickly exhausted. Characterized by the presence of a savannah-like open tree layer, mainly dominated by Mediterranean evergreen oaks – holm oak (*Quercus ilex*) and cork oak (*Q. suber*) – and to a lesser extent by the deciduous *Q. pyrenaica* and *Q. Faginea,* dehesas are usually found on acid soils originating from siliceous, which is poor in nutrients and has shallow soils (rarely > 50 cm). This low fertility has limited its use for growing crops. Soil variability is high in the dehesas as a result of erosion, transportation and sedimentation processes from hillsides and seasonal streams. The soil is mostly luvisols, leptosols and cambisols with different depths and development.

Selection of Dehesa Soil Data

A large number of collections of available published data from different soil surveys of Spanish dehesa systems were consulted. Finally, we selected information on 110 dehesa stands previously published in three main soil databases: 55 geopoints were extracted from Pulido-Fernández et al. (2015); 26 geopoints belonging to the soil database generated in the framework of the ICP-Forest Programme (International Cooperation Programmes) and published by Moreno and López-Arias (1997); 30 geopoints belonging to the soil database generated in the framework of the Red CARBOSOL Project and published by Llorente et al. (2018). The point selection criteria in the literature were 1) georeferenced profiles of at least 30 cm depth (separated in 0-5, 5-10 and 10-30 cm); 2) description of soils' physico-chemical characteristics (bulk density, pH, soil texture fractions, N, CEC, K, Mg, Ca); 3) sampling date at least 10 years prior to our sampling year (2018). The sampling points were well distributed throughout the Iberian dehesa region (Fig. 1) and ranged from 1959 to 2006.

Figure 1. Soil sampling points distribution



Soil Sampling and Analysis

The soil sampling methodology was followed according to the ICP Forests Manual (Cools & De Vos, 2016). Quadrupled samples of soil, till 30 cm depth, were extracted in each selected geopoint. Separated subsamples of 0-5, 5-10 and 10-30 cm depth were dried, sieved (< 2mm) and stored in plastic bags. Milled samples were analyzed for C and N by a LECO C.N.H.S. Elemental Analyzer (Model CHNS-932, LECO Corporation, St Joseph, Michigan, USA).

Soil Carbon Stocks and Their Change Rates Calculation

SOC stock (SOC_{stock}) per unit area (Ton of C $\cdot ha^{-1}$) was estimated according to Eq. 1:

$$SOC_{stock} = SOC * BD * T \quad (1)$$

Where SOC is the C concentration in the soil sample, BD is bulk density (g cm^{-3}) and T is layer thickness (30 cm, according to EU directive).

The SOC_{stock} change rate (ΔSOC_{stock}) per unit area and time (Ton of C ·ha^{-1}·year^{-1}), equivalent to the C sequestration rate, was estimated according to Eq. 2:

$$\Delta SOC_{stock} = (SOC_{stock\_t2} - SOC_{stock\_t1}) / (t_2 - t_1) \quad (2)$$

Where SOC_{stock} is the SOC stock per unit, t_1 is the year of first sampling and t_2 is the year of second sampling.

Forest Inventory Data Management

We selected information from the Second Spanish Forest Inventory (IFN2) and Third Spanish Forest Inventory (IFN3) from Extremadura, Andalucía, Castilla la Mancha and Castilla León regions. IFN2 was conducted for those regions between 1990 and 1996, while IFN3 was conducted between 2000 and 2008. In this study, we selected 3,823 dehesa plots following the criteria: a) points that were sampled in both IFN2 and IFN3; b) main tree species (>50%) represented by *Quercus sp*. or *Olea europaea*; c) forest density of below 80 trees·ha^{-1}. Criteria b) and c) were established following the definition of dehesa systems of Pulido and Picardo (2010). IFNs comparison and management was done using Basifor 2.0 software (Bravo et al., 2001).

In both surveys, forest plots were divided into four nested circular subplots (with a radius of 5, 10, 15 and 25 m); and trees were recorded only if their diameter was larger than a certain threshold (7.5, 12.5, 22.5 and 42.5, respectively). Species identity, height and diameter at breast height (d.b.h.) of living and standing dead trees were available for both surveys. On a circular plot with a 5 m radius, the number of saplings per species (2.5 cm ≤d.b.h. < 7.5 cm) and their mean height was also recorded. Species identity, canopy cover and mean height of woody understory vegetation was sampled within the 10-m radius plot.

Tree Biomass Carbon Stocks and Their Change Rate Calculation

Structural measurements of IFN2 and IFN3 for all 3,823 selected plots were converted to biomass carbon densities by using allometric equations. IPCC (2006) guide equations for above and belowground tree biomass was used, however specific Biomass Expansion Factor (BEF), Root-to-Shoot Ratio (R), and Carbon Fraction (CF) for each species were used when available in the Montero et al. (2005) database.

Tree biomass stock (including above and belowground) per unit of area (Ton of dry matter ·ha^{-1}) was estimated according to Eq. 3:

$$Bha = VOB*BEF*(1+R) \quad (3)$$

Where VOB is volume over bark (m^3 ha^{-1}), BEF is the biomass expansion factor and R is the ratio of aboveground oven-dry biomass of tree to belowground oven-dry biomass.

C biomass stock (including above and belowground) per unit of area (Ton of C ·ha^{-1}) was estimated according to Eq. 4:

$$CB = Bha*CF \quad (4)$$

Where CF is the specific C fraction for each species.

The CB change rate (ΔCB) per unit area and time (Ton of C $\cdot ha^{-1} \cdot year^{-1}$), equivalent to the C sequestration rate, was estimated according to Eq. 5:

$$\Delta CB = (CB_{t2} - CB_{t2}) / (t_2 - t_1) \quad (5)$$

Where CB is the C biomass stock per unit area, t_1 is the year reported in IFN2 and t_2 is the year reported in IFN3.

Statistical Analysis

Analysis of variance (ANOVA) was used to compare variables. In case of significant F-statistics ($p>0.05$), differences between means were tested with the Tukey procedure for multiple comparisons. Data were tested for normality and homoscedasticity with the Kolmogorov-Smirnov and Levene's statistics respectively. The statistical analyses were carried out using R software (R Core Team, 2017).

RESULTS AND DISCUSSION

Soil C Stocks and Soil C Sequestration Rate of Iberian Dehesa Systems

Most soil samples corresponded with Haplic Cambisols (96%) and several others to Haplic Luvisols. The main physical and chemical properties of soils sampled throughout the dehesa ecosystem are displayed in Table 1.

Table 1. Characteristics of Dehesa Soils in Spain.

Soil property	Mean ± sd	Max	Min
Clay (%)	11.8 ± 7.7	30.0	2.6
Bulk Density. ($g \cdot cm^{-3}$)	1.45 ± 0.15	1.74	1.08
pH (aq)	5.61 ± 0.77	7.84	4.21
CEC ($cmol \cdot kg^{-1}$)	10.1 ± 5.9	24.5	3.6
Ca (ppm)	1011 ± 514	2400	220
Mg (ppm)	255 ± 162	1305	37
K (ppm)	125 ± 123	821	22
Na (ppm)	70 ± 32	276	23
N ($g \cdot kg^{-1}$)	1.52 ± 1.08	6.30	0.40

Data refer to mean and standard deviation (sd) values of the 110 soil samples.

C sequestration can be defined as the uptake of C-containing substances and, in particular, CO_2 into another reservoir with a longer residence time (IPCC, 2007). Ideally, SOC sequestration should be reported as rates (in mass SOC per unit of area and time). However, SOC sequestration data are mostly reported as pools or stocks. We know that some SOC in agroforestry systems may persist for millennia, indicating that terrestrial sequestration for climate change mitigation occurs particularly by avoiding net SOC losses and the slowly ongoing accumulation of the slowest SOC pool (Mbow et al., 2014; Schmidt et al., 2011). In our study we found that the dehesa system ad an annual growth rate of soil C stock of around 11‰, greatly above the proposed '4 per mille Soils for Food Security and Climate' of the Lima-Paris Action Agenda. The aim of using dehesa systems for climate change mitigation purposes should be to reduce SOC losses and enhance SOC stabilization. It should be mentioned that in the past few decades, the degradation of the dehesa system by land use change, lack of tree regeneration and disease (particularly, the root caused by the pathogen *Phytophthora cinnamomi*) has threatened to undermine the potential secondary environmental benefits provided by these systems. Agroforestry systems have higher C stocks in aboveground biomass as compared with treeless pastures, or natural grasslands (Nair et al., 2014), and there is also evidence that C storage in deep soil horizons is greater in a number of AF systems (Lorenz and Lal, 2014). Therefore, the Kyoto Protocol recognized AF systems as a strategy for soil carbon sequestration (IPCC, 2006).

The current mean stock of C in soils (0-30 cm depth) of the Iberian dehesa is 72.0 Ton of C $\cdot ha^{-1}$ with great variability between sites, ranging from 25.3 to 149.9 Ton of C $\cdot ha^{-1}$. For the same soil profile depth, we found a SOC concentration average growth rate of 0.20 g $C \cdot kg^{-1} \cdot year^{-1}$ (ranging from -0.62 to 1.61 g $C \cdot kg^{-1} \cdot year^{-1}$), corresponding to a SOC sequestration rate average of 0.83 Ton of $C \cdot ha^{-1} \cdot year^{-1}$ (ranging from -2.51 to 5.57 Ton of $C \cdot ha^{-1} \cdot year^{-1}$). In addition, we found, for an average interval of 22 years, that the mean content of soil C increased from 1.35 to 1.66%, which translates into a mean accumulation in the uppermost 30 cm of the soil equivalent to 0.83 $Ton \cdot ha^{-1} \cdot year^{-1}$. The same change patterns were found for the 0 to 5 cm soil profile interval as is shown in Table 2, although more intensity of C sequestration for that depth interval was estimated, with a SOC concentration average growth rate of 0.28 g $C \cdot kg^{-1} \cdot year^{-1}$ (ranging from -1.00 to 2.70 g $C \cdot kg^{-1} \cdot year^{-1}$).

Table 2. Soil C Density, Stocks and Sequestration Rate.

Soil property	X_{t1} (mean ± sd)	X_{t2} (mean ± sd)	X_{t2} - X_{t1}	(X_{t2} - X_{t1}) /(t2-t1)
Year	1996 ± 13.0	2018 ± 0.0	22.11 ± 13.0	1.00 ± 0.0
%OC (0-5 cm)	1.51 ± 0.81	1.83 ± 1.19	0.31 ± 0.95	0.02 ± 0.05
%OC (0-30 cm)	1.35 ± 0.57	1.66 ± 0.63	0.31 ± 0.61	0.02 ± 0.04
SOC_{stock} (0-5 cm)	13.43 ± 6.12	15.67 ± 8.00	2.24 ± 7.56	0.15 ± 0.44
SOC_{stock} (0-30 cm)	58.70 ± 25.21	72.02 ± 26.55	13.32 ± 26.19	0.83 ± 1.55

Data refer to mean and standard deviation (sd) values of the 110 soil samples. SOC_{stock} expressed in Ton of C $\cdot ha^{-1}$ and t_n in years.

C sequestration in soils varies widely depending on the agroforestry system, but, given the same climatic and edaphological conditions, usually agroforestry systems have more C sequestration capacity than tree plantations or crops (Nair et al., 2009). Studies on SOC sequestration rates in AF systems report rates from -0.39 Ton $C \cdot ha^{-1} \cdot year^{-1}$ for cacao+canopy trees in agroforestry in Ghana (Isaac et al., 2005) to 4.16 $C \cdot ha^{-1} \cdot year^{-1}$, as reported by Beer et al (1990) for cacao+*Erythrina poeppigiana,* in Costa Rica's agroforest system. Oelbermann et al. (2006) indicated that although tropical agroforestry systems may have higher SOC sequestration rates, temperate systems may be more effective in soil stabilization because of the residue C inputs from tree prunings, litterfall, and crop residues. Native soil C levels reflect the balance of C inputs and C losses under native conditions, but do not necessarily represent an upper limit in soil C stocks. Empirical evidence demonstrates that C levels in intensively managed agricultural and pastoral ecosystems can exceed those under native conditions. Greater soil C stocks directly underneath the tree canopy suggest that maintaining or increasing tree cover, may increase long term storage of soil C in dehesa silvopastoral systems. The processes contributing to sequestration rates and the stabilization of SOC in agroforestry soils need additional data and research.

Soil C Saturation Level and C Sequestration Potential.

Most current models of SOM dynamics assume first-order kinetics for the decomposition of various conceptual pools of organic matter, which means that equilibrium C stocks are linearly proportional to C inputs (Paustian et al., 2007). These models predict that soil C stocks can, in theory, be increased without limit, without the assumptions of soil C saturation. However, especially for soils with low to moderate C levels (e.g. <5%), there is evidence of a carbon saturation level (Solberg et al., 1997). There are several lines of evidence that suggest the existence of a C saturation level based on physicochemical processes that stabilize or protect organic compounds in soils. The soil C saturation concept suggests that with increasing C inputs, the SOC stock will reach a maximum, and the SOC accumulation rate will decrease during this process (Six et al., 2002). The difference between the saturated organic C content in the fine fractions and the actual measured organic C content of these fractions is referred to as the stable soil C saturation deficit (Six et al., 2002). This soil C saturation deficit affects the ability of soils to store C inputs in a stable form and indicates the potential of a soil for sequestering C. Nevertheless, C may accumulate beyond the hypothetical soil C saturation threshold. Plants producing low-quality FOC (fresh organic carbon) can promote soil C sequestration beyond the hypothetical saturation threshold. The saturation concept is only applicable to SOC stabilized by microbial activity, while the particulate-recalcitrant C would continue to increase beyond the saturation level (Castellano, 2015).

In accordance with the soil C saturation concept, we found a significant decrease (Slope= -0.022; R^2= 0.292; p <0.001) in the SOC change rate related to the initial SOC concentration (*Fig 2*), which indicates greater sequestration rates in originally poorer soils. Fitting a model following this SOC saturation concept allowed for an estimation of the average soil C storage potential of around 2.8%, way above the current 1.7% mean content. We found a theoretical SOC storage capability of around 1.1%, which differed greatly to the current average content, indicating a great future potential for storing C in dehesa soils.

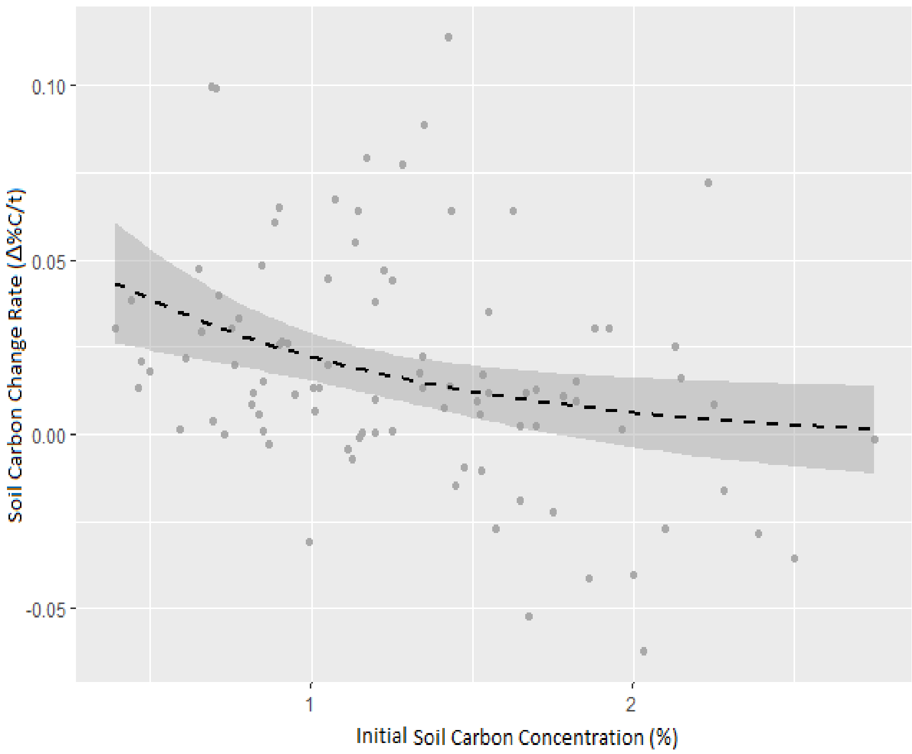


Figure 2. Soil Carbon change ratio with respect to the initial soil carbon concentration

Tree Biomass C Stocks and Changes

A total of 3,823 plots were selected from both IFNs. *Quercus ilex* was the dominant tree species in the majority of the dehesa plots (88.6%), followed by *Quercus suber* (5.4%) and *Quercus pyrenaica* (4.9%). We rarely found dehesa systems dominated by *Quercus faginea* or *Olea europaea*. Average tree structure characteristics of both IFNs and their comparison are shown in Table 3.

The current mean C stock in tree biomass of dehesa systems is 8.05 Ton of C $\cdot ha^{-1}$, with great variability between sites, ranging from 1.13 to 30.82 Ton of C $\cdot ha^{-1}$. The mean C sequestration rate of trees in dehesa systems amounted to 0.078 ± 0.19 Ton of C$\cdot ha^{-1} \cdot year^{-1}$, with this rate of change ranging from -3.03 and 1.30 Ton of C$\cdot ha^{-1} \cdot year^{-1}$. As is shown in Figure 3, increases in tree biomass C stocks tended to be greater in those plots with lower biomass C stocks at IFN2.

Table 3. Iberian Dehesa Tree Biomass Characteristics

	IFN2	IFN3	ΔIFN3-IFN2
Year	1991 ± 1.7	2002 ± 1.9	10.84 ± 0.6
Tree number (indiv$\cdot ha^{-1}$)	35.1 ± 18.7	35.3 ± 18.7	0.11 ± 10.0
d.b.h. (cm)	4.5 ± 2.4	4.9 ± 2.5	0.38 ± 1.0
Total Height (cm)	6.5 ± 1.5	7.5 ± 1.6	0.59 ± 1.1

VOB ($m^3 \cdot ha^{-1}$)	8.96 ± 5.19	10.02 ± 5.59	1.06 ± 2.67
Tree biomass stock* ($Ton \cdot ha^{-1}$)	15.15 ± 8.81	16.96 ± 9.46	1.80 ± 4.47
C biomass (Ton of $C \cdot ha^{-1}$)	7.19 ± 4.18	8.05 ± 4.49	0.86 ± 2.12

**Tree biomass stock is expressed as oven dry matter*

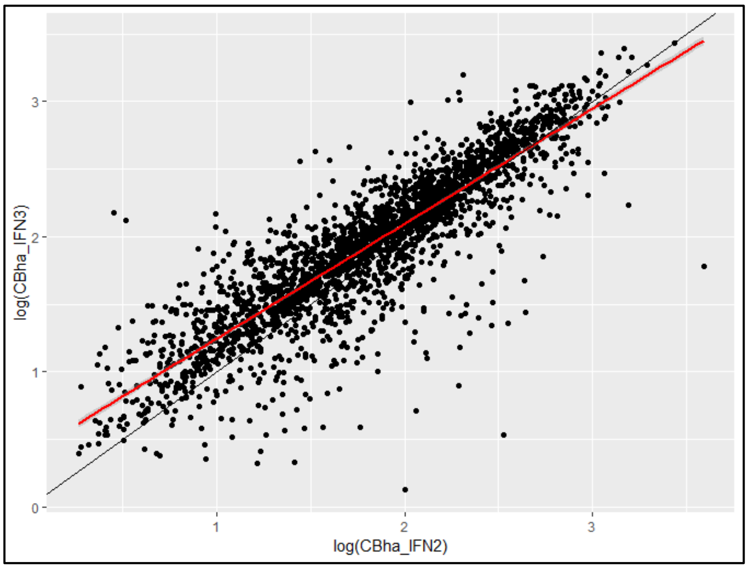


Figure.3. Biomass tree Carbon comparison IFN2 vs. IFN3. Logarithmic transformation of variables is represented.

C sequestration occurs in trees in dehesa systems, both in belowground biomass (i.e., branch, foliage or stem) and aboveground biomass (i.e. roots, and rhizosphere). Aboveground, the tree root-derived C inputs are a great source for the SOC pool in deeper horizons (Kell, 2012). In parallel, tree roots have the potential to recover nutrients from below the crop rooting zone, resulting in an enhancement of tree and crop growth by subsequent increase in nitrogen nutrition, which may result in an increase in SOC sequestration (Van Noordwijk et al., 1996). Belowground, trees modify the quality and quantity of litter C inputs and modify microclimatic conditions such as soil moisture and temperature regimes (Laganière et al., 2010).

Comparing tree biomass C stocks in each plot, grouping data by dominant tree species, we found significant differences between the groups (F-value= 8.280, $p<0.001$). A Tukey post-hoc test indicated that those plots dominated by *Q.ilex and Q.suber* had significantly greater biomass C stocks than those dominated by *Q.pyrenaica* ($p<0.001$). Significant differences ($p<0.01$) were also found between plots dominated by *Q.ilex* and those dominated by *Q.suber* with a greater average C stock for *Q.suber* systems (Fig 4.). The comparison of biomass C sequestration rates, grouping by dominant tree species, also shows differences by group (F-value= 5.231, $p<0.001$). A Tukey post-hoc test revealed the same data behaviour as for C biomass stocks, with significantly greater C stock sequestration rates for dehesas dominated by *Q.ilex* and *Q.suber* than those dominated by *Q.pyrenaica,* and higher rates for dehesas dominated by *Q.suber* than those dominated by *Q.ilex* (Fig 4.).

It has been argued that old forests are unimportant in addressing the climate change problem because carbon offset investments focus on planting young trees, as their rapid growth provides a higher sink capacity than old trees. Recent research findings have demonstrated that old-growth forests are likely to function as carbon sinks (Luyssaert et al., 2008). The considerable length of time it takes new plantings to sequester and store the amount of carbon equivalent to that stored in mature forests counters the argument regarding the rapid growth of young trees. In that sense, it is useful to distinguish between the carbon carrying capacity of an ecosystem and its current carbon stock. Carbon carrying capacity is the mass of carbon able to be stored in a tree-dominated ecosystem under prevailing environmental conditions. It is a landscape-wide metric that provides a baseline against which current carbon can be compared. The difference between carbon carrying capacity and current carbon stock allows an estimate of the carbon sequestration potential of an ecosystem.

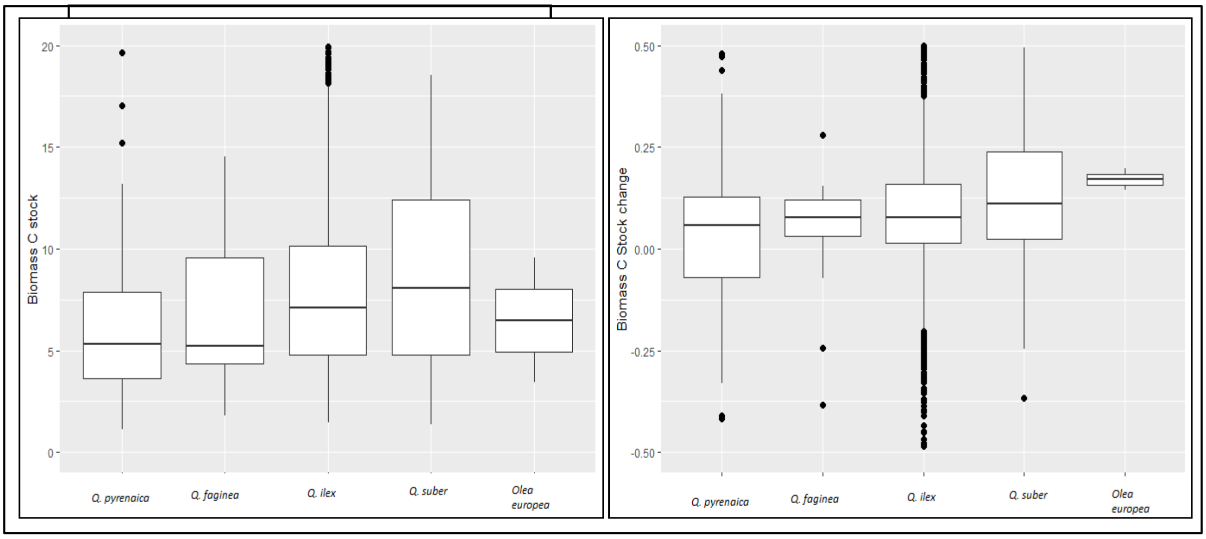


Figure.4. Boxplot of the tree biomass C stock (Ton of C·ha^{-1}) and tree biomass C sequestration rate (Ton of C ·ha^{-1}·year^{-1}) represented by dominant tree species in the dehesa plot.

Towards Neutral Carbon Farming Systems

There is a potential to sequester C in soil and tree biomass by conservation and good management practices of dehesa systems. The livestock sector, globally, represents 12% of all human GHG emissions (Havlik et al., 2014). However, it is important to distinguish livestock farming systems when we are trying to assess animal production's climate responsibility. Pastoral systems are closely linked to the conservation of dehesa systems and grasslands, and soil CO_2 sequestration in grasslands has a great mitigation potential (Crosson et al., 2011). We argue that pastoral-based production systems come close to representing a carbon-neutral emissions production method.

Specifically, our study on GHG sink and source balance in dehesa systems indicates that extensive livestock systems linked to dehesa system conservation comes close to being zero-emission production. The C sequestration capacity of dehesa soils was estimated at 0.827 Ton of C·ha^{-1}·year^{-1} (0-30 cm), while the C sequestration in the trees amounts to an equivalent of 0.078 Ton of C·ha^{-1}·year^{-1}. In summary, soils and tree biomass together add up to an average sink of 0.905 Ton of C·ha^{-1}·year^{-1}. This C sequestration rate would offset most of the emissions of GHG estimated for the extensive livestock farming systems produced in the dehesa. Eldesouky et al. (2018) have estimated emissions of 1.066 Ton of C·ha^{-1}·year^{-1} for extensive beef farms and of 1.319 Ton of C·ha^{-1}·year^{-1} for the extensive meat sheep farms, including on- and off-farm emissions. Taking into account that the 3rd quartile of soil C and tree biomass C sequestration rates estimated in our study were 1.461 Ton of C·ha^{-1}·year^{-1} and 0.161 Ton of C·ha^{-1}·year^{-1}, respectively, we can suppose that an improvement in the management of the soil and vegetation of dehesa systems could increase the current C sequestration rate of farms located within these systems.

From here we can conclude that, currently, C sequestration in soil and trees of the Iberian dehesa offsets most of the GHG emissions associated to extensive livestock production systems, and even has the potential to sequestrate more C than these systems emit, making it a net sink GHG food production system. These results provide clear indications of the possibilities for climate change mitigation and even opportunities for economic benefit through carbon trading. Therefore, managing carbon flows in agroforestry ecosystems more efficiently is central to limiting climate change. It is important to note that processes contributing to sequestration rates and the stabilization of SOC in agroforestry soils need additional data and research.

REFERENCES

Beer, J., Bonnemann, A., Chavez, W., Fassbender, H.W., Imbach, A.C., Martel, I., 1990. Modelling agroforestry systems of cacao (*Theobroma cacao*) with laurel (*Cordia alliodora*) or poro (*Erythrina poeppigiana*) in Costa Rica. Agroforestry Systems, 12, 229-249 pp.

Bravo, F., Ordóñez, A.C., Del Río, M. 2005. BASIFOR 2.0: Aplicación informática para el manejo de bases de datos del Segundo y del Tercer Inventario Forestal Nacional.

Castellano, M.J., Mueller, K.E., Olk, D.C., Sawyer, J.E., Six, J., 2015. Integrating plant litter quality, soil organic matter stabilization, and the carbon saturation concept. Global Change Biology, 21, 3200-3209 pp.

Cowie, A.L., Penman, T.D., Gorissen, L., Winslow, M.D., Lehmann, J., Tyrrel, T.D., Twomlow, S., Wilkes, A., Lal, R., Jones, J.W., Paulsch, A., Kellner, K., Akhtar-Schuster, M., 2011. Towards sustainable land management in the drylands: Scientific connections in monitoring and assessing dryland degradation, climate change and biodiversity. Land Degradation and Development, 22, 248-260 pp.

Crosson, P., Shalloo, L., O'Brien, D., Lanigan, G.J., Foley, P.A., Boland, T.M., Kenny, D.A., 2011. A review of whole farm system models of greenhouse gas emissions from beef and dairy cattle production systems. Animal Feed Science Technology, 166-167, 29-45 pp.

Doetterl, S., Stevens, A., Six, J., Merckx, R., Van Oost, K., Casanova Pinto, M., Casanova-Katny, A., Muñoz, C., Boudin, M., Venegas, E.Z., Boeckx, P., 2015. Soil carbon storage controlled by interactions between geochemistry and climate. Nature Geoscience.

Eldesouky, A., Mesias, F.J., Elghannam, A., Escribano, M., 2018. Can extensification compensate livestock greenhouse gas emissions? A study of the carbon footprint in Spanish agroforestry systems. Journal of Cleaner Production, 200, 28-38 pp.

Havlik, P., Valin, H., Herrero, M., Obersteiner, M., Schmid, E., Rufino, M.C., Mosnier, A., Thornton, P.K., Bottcher, H., Conant, R.T., Frank, S.., Fritz, S., Fuss, S., Kraxner, F., Notenbaert, A., 2014. Climate change mitigation through livestock system transition. Proceedings of the National Academy of Sciences, 111, 3709-3714 pp.

Hengl, T., Mendes de Jesus, J., Heuvelink, G. B., Ruiperez Gonzalez, M., Kilibarda, M., Blagotić, A.,Kempen, B. (2017). SoilGrids250m: Global gridded soil information based on machine learning, edited by B. Bond-Lamberty. PLoS One, 12(2)

Herrero, M., Havlik, P., Valin, H., Notenbaert, A., Rufino, M.C., Thornton, P.K., Blummel, M., Weiss, F., Grace, D., Obersteiner, M., 2013. Biomass use, production, feed efficiencies, and greenhouse gas emissions from global livestock systems. Proceedings of the National Academy of Sciences, 110, 20888-20893 pp.

Howlett, D. S., Moreno, G., Losada, M. R. M., Nair, P. R., Nair, V. D., 2011. Soil carbon storage as influenced by tree cover in the Dehesa cork oak silvopasture of central-western Spain. Journal of Environmental Monitoring, 13(7), 1897-1904 pp.

IPCC, 2007. Climate change 2007: synthesis report. In: Core Writing Team, Pachauri, R.K., Reisinger, A., (eds). Contribution of working groups I, II, and III to the fourth assessment report of the intergovernmental panel on climate change. IPCC, Geneva.

IPCC, 2006. IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. y Tanabe K. (eds). Published by: IGES, Japan.

Isaac, M.E., Gordon, A.M., Thevathasan, N.V., Oppong, S.K., Quashi-Sam, J., 2005. Temporal changes in soil carbon and nitrogen in west African multistrata agroforestry systems: a chronosequence of pools and fluxes. Agroforestry Systems, 65, 23-31 pp.

Joffre, R., Rambal, S., Ratte, J.P., 1999. The dehesa system of southern Spain and Portugal as a natural ecosystem mimic. Agroforestry systems, 45, 57-79 pp.

Kell, D.B., 2012. Large-scale sequestration of atmospheric carbon via plant roots in natural and agricultural ecosystems: why and how. Philosophical Transactions of the Royal Society B: Biological Sciences, 367, 1589-1597 pp.

Laganiére, J., Angers, D., Paré, D., 2010. Carbon accumulation in agricultural soils after afforestation: a meta-analysis. Global Change Biology, 16, 439-453 pp.

Litton, C.M., Giardina, C.P., 2008. Below-ground carbon flux and partitioning: global patterns and response to temperature. Functional Ecology, 22, 941-954 pp

Lorenz, K., Lal, R., 2014. Soil organic carbon sequestration in agroforestry systems. A review. Agronomy for Sustainable Development, 34 (2), 443-454 pp.

Llorente M., Rovira, P., Merino, A., Rubio, A., Turrión, M.B., Badía, D, Romanya, J., González, J.A., Cortina, J., 2018. The CARBOSOL Database: a georefered soil profile analytical database for Spain. *PANGAEA Open Data Publisher.*

Luyssaert, S., Schulze, E-D., Börner, A., Knohl, A., Hessenmöller, D., Law, B.E., Ciais, P., Grace, J., 2008. Old-growth forests as global carbon sinks. Nature 455 (7210), 213-5 pp.

Mbow, C., Smith, P., Skole, D., Duguma, L., Bustamante, M., 2014. Achieving mitigation and adaptation to climate change through sustainable agroforestry practices in Africa. Current Opinion in Environmental Sustainability, 6, 8-14 pp.

Montero, G., Ruiz-Peinado, R., Muñoz, M., 2005. Producción de biomasa y fijación de CO2 por los bosques españoles. Monografías INIA, Serie Forestal 13. Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, Ministry of Education and Science, Madrid, Spain.

Montoya, R., López-Arias, M., 1997. La Red Europea de Puntos de Seguimiento de Daños en los Bosques (Nivel I) en España. Ministry of Environment, Publicaciones del O.A. Parques Nacionales. Madrid.

Moreno, G., Cubera, E., 2008. Impact of stand density on water status and leaf gas exchange in Quercus ilex. Forest Ecology and Management, 254(1), 74-84.

Moreno, G., Pulido, F.J., 2008. The functioning, management and persistence of dehesa. In: Rigueiro-Rodriguez, A., McAdam, J., Mosquera-Losana, M. (Eds.). Agroforestry in Europe: Current Status and Future Prospects. Springer Science and Business Media, 127-160 pp.

Nair, P.K.R., Nair, V.D., 2014. "Solid-fluid-gas": the state of knowledge on carbon-sequestration potential of agroforestry systems in Africa. Current Opinion in Environmental Sustainability, 6, 22-27 pp.

Nair, P.K.R., Nair, V.D., Gama-Rodrigues, E.F., Garcia, R., Haile, S.G., Howletta, D.S., Kumar, B.M., Mosquera-Losada, M.R., Sahaa, S.K., Takimoto, A.N.G., Tonucci, R.G., 2009. Soil Carbon in Agroforestry Systems: An Unexplored Treasure?. Nature Precedings.

Oelbermann, M., Voroney, R.P., Gordon, A.M., Kass, D.C.L., Schlönvoigt, A.M., Thevathasan, N.V., 2006. Soil carbon dynamics and residue stabilization in Costa Rican and southern Canadian alley cropping system. Agroforestry Systems, 68, 27-36 pp.

Paustian, K., Andrén, O., Janzen, H.H., Lal, R., Smith, P., Tian, G., Tiessen, H., Van Noordwijk, M., Woomer, P.L., 2007. Agricultural soils as a sink to mitigate Co2 emissions, Soil Use and Management, 13, 230-244 pp.

Pulido-Fernández, M., Schnabel, S., Lavado, J.F., Sevillano, H., González, F., 2015. Soil quality indicators and pasture production in SW Iberian rangelands. Iberian Ecology Congress, Coimbra.

Pulido, F., Picardo, A. (coords.), 2010. Libro verde de la dehesa. Document for the debate on an Iberian management strategy.

R Core Team (2017). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Rodeghiero M, Rubio A, Díaz-Pinés E, Romanyà J, Marañón S, Levy G, Sebastiá T, Fernández-Getino AP, Karyotis T, Chiti T, Sirca C, Martins A, Madeira M, Zhiyanski M, Gristina L (2011) Mediterranean ecosystems. In: Jandl R, Olssons M, Rodeghiero M (eds) Soil carbon in sensitive European ecosystems. John Wiley & Sons, West Sussex, UK.

Ruiz-Peinado, R., Moreno, G., Juarez, E., Montero, G., Roig, S., 2013. The contribution of two common shrub species to aboveground and belowground carbon stock in Iberian dehesas. Journal of Arid Environments, 91, 22-30 pp.

Ruiz-Peinado, R., Moreno, G., del Río, M., 2012. Biomass models to estimate carbon stocks for hardwood tree species. Forest Systems, 21, 42-52 pp.

Schmidt, M.W.I., Torn, M.S., Abiven, S., Dittmar, T., Guggenberger, G., Janssens, I.A., Kleber, M., Kögel-Knabner, I., Lehmann, J., Manning, D.A.C., Nannipieri, P., Rasse, D.P., Weiner, S., Trumbore, S.E., 2011. Persistence of soil organic matter as an ecosystem property. Nature, 478, 49-56 pp.

Six, J., Conant, R.T., Paul, E.A., Paustian, K., 2002. Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. Plant and Soil, 241, 155–176 pp.

Solberg, E.D., Nyborg, M., Izaurralde, R.C., Mahli, S.S., Janzen, H.H., Molina-Ayala, M., 1997. Carbon storage in soils under continuous cereal grain cropping: N fertilizer and straw. In: Stewart, B.A. (eds) Management of carbon sequestration in soil. CRC Press, Boca Raton, FL, 235–213 pp.

Van Noordwijk, M., Lawson, G., Soumare, A., Groot, J.J.R., Hairiah, K., 1996. Root distribution of trees and crops: competition and/or complementarity. In: Ong C.K., Huxely, P., (eds) Tree-crop interactions, a physiological approach. CAB International, Wallingford, 319-364 pp.

Waldron, A., Garrity, D., Malhi, Y., Girardin, C., Miller, D.C., Seddon, N., 2017. Agroforestry can enhance food security while meeting other sustainable development goals. Tropical Conservation Science, 10, 1-6 pp.

Young, A., 1997. Agroforestry for soil management. CAB International and ICRAF, Wallingford.

HORTICULTURAL AGROFORESTRY: THE CHALLENGE OF DIVERSIFICATION SERVICES

Tchamitchian, Marc, Alfonzo-López, Dayaleth, Raphaël Paut, Rodolphe Sabatier, Romain Roche

INRA, ECODEVELOPPEMENT, France

Abstract: Agriculture specialization and intensification has led to a biodiversity loss in while this biodiversity fulfils several services in agroecosystems, among which natural regulations and pest control. Cropping system diversification is a promising answer to these challenges, in the frame of agroecological transitions of agriculture. In this context, agroforestry combines diversification with other potential services, densification of the production, synergies between crops, enhancing natural regulations, and seems a very promising opportunity. Following this line, horticultural agroforestry, mixing fruit trees and vegetable crops on the same plot is gaining momentum as a strategy to address both the consumer demand and these ecological goals. These systems embed a high biological diversity, through the association of several crops at the same on time on the same plot, and through the large number of crops in rotation along time.

However, recent works points out that some of those services are not so favorable as hypothesized. For example, a positive link between the increase of the number of crops and the number of different enemies has been shown, with consequences on the damages to the crops, also increasing with the number of different crops. On the contrary, production variability has been shown to decrease while diversification increases, at the expanse of the total productivity, unless synergies between crops are exploited (associating crops with Land Equivalent Ratios larger than one). It appears therefore that the diversification has contrasted effects, making the evaluation of its benefits a real challenge.

In this presentation we will propose a framework to guide the evaluation of the balance between these different services, in relation to the structure and the composition of the horticultural agroforestry system at hand. This framework would therefore allow to support the design of such systems, in terms of complexity and in terms of organization.

RETRO-INNOVATION AS A TOOL TO ADDRESS KEY ENVIRONMENTAL CHALLENGES – THE CASE OF ACORN CONSUMPTION IN PORTUGAL

Ana Margarida Fonseca[a], Teresa Pinto-Correia[b], Ana Cristina Agulheiro[c], Filipa Cachapa[d]

[a] Instituto de Ciências Agrárias e Ambientais Mediterrânicas
[b] Instituto de Ciências Agrárias e Ambientais Mediterrânicas
[c] Instituto de Ciências Agrárias e Ambientais Mediterrânicas
[d] Instituto de Ciências Sociais da Universidade de Lisboa

Abstract:

There has been a growing interest in using old products which have represented important resources in the past but the growing urbanization of lifestyles has led to oblivion. Although these products and linked practices are far from the current market economy that make intensive use of energy and other inputs, they can represent a contribution to deal with the major environmental and social challenges we face today. Acorns represent an important production of Portuguese forest. Although being nowadays used mainly as livestock feed, acorns were used directly as part of the human diet for centuries. Its consumption decreased due to the progressive improvement in living conditions of the rural population and the influence of the urban culture in the countryside. In recent years, the use of acorns has been re-introduced as niche activities, by some agri-food companies, interested in diversifying the sources of income. The number of companies exploring the acorn as well as the number of acorn-based products were also been growing, initially more inspired by recipes used in the past and, more recently, with a higher degree of technology incorporation. We propose to explore these retro-innovations as a way to contribute to maintain acorns producing systems, without compromising them, and we will dwell on its potential as a tool to responding to present and future challenges related with climatic change, the need for decarbonising the economy, to overcome the nutritional impoverishment of our menus and to explore new ways of managing resources.

1. Introduction:

In Portugal acorns can come from two main systems, the deciduous oaks forests distributed roughly in the north of the country and managed as silvo-pastoral systems with extensive grazing or denser forested areas exploited for timber (Acácio et. Al. 2017) and the *Montados*, a silvo-pastoral system which spreads mainly in the south. In the northern oak forests, the main oaks species found are *Quercus robur*, *Quercus faginea* and *Quercus pyrenaica* (ICNF, 2016). In the southern *Montados*, the acorns are produced mainly by *Quercus rotundifolia* (holm oak) and *Quercus suber* (cork oak) (Bingre et al., 2007; Acácio et al., 2017). In the northern oaks' forests, goats can use several resources as shrubs and trees leaves and branches (Castro et al., 2017). In the *Montado* system tree canopy coexists with natural pastures and some shrubs with the main intent of cattle production (Pinto-Correia et al., 2011; Sá Sousa, 2014). In *Montado* livestock rearing is the major source of income in areas where holm oaks dominate (areas with higher continentality index) and cork income dominates in cork oak areas (areas with greater Atlantic influence). Both northern oaks forests and Montados are generally recognised as sustainable systems (Pinto-Correia et al., 2011; Mosquera-Losada, 2012; Castro et al. 2009) being, the first, a 2000 Natura Site "Carvalhais Galaico-portugueses de *Quercus robur* e *Quercus pyrenaica* – Nº 9230" from Habitats Directive (Council Directive 92/43/EEC of 21 May 1992), and the later recognised as high natural value systems at a European level (Almeida et al., 2013; Pinto-Correia et al., 2018). These systems also provide a wide range of ecosystem services and public goods (Bugalho et al., 2009; Gómez-

Sal, 2000; Castro et al. 2009), which are of critical importance to well-being (Surová et al., 2018) besides representing landscapes with strong identitarian features.

However, these systems are threatened by several factors as overgrazing (Sales-Baptista et al. 2015; Plieninger 2007; Pulido and Díaz 2005; Godinho et al. 2016), fires (Guiomar et al., 2015), drought (Camilo-Alves et al., 2017; Acácio et al., 2017), plant pathogens (Camilo-Alves et al., 2013), insect pests (Tiberi et al., 2016, Branco et al., 2014) and habitat fragmentation (Nieto Quintano at al., 2016), aggravated by climate change that has higher impact on the Mediterranean region, enhancing all these threats to oak systems (IPCC 2014).

Holm oak acorns are generally more edible than acorns coming from the other oak species, but this varies widely with the holm oak trees that have a large genetic diversity and local variability (Mason 1995) in the characteristics of the acorn they produce. This is a species mechanism to prevent pests like *Curculio elephas* Gyll. (Coleoptera; Curculionidae) and *Cydia* spp (Lepidoptera, Tortricidae) (Gea-Izquierdo et al. 2006, Branco et al. 2014).

Thus, acorns may have a higher or lower tannin content, which gives it a bitter taste, but also antioxidant characteristics and lower digestibility, and may have a higher or lower sugar content. In order to increase the sugar content, it is advantageous to wait for the full maturation of the fruit, which occurs between November and December (Ferraz de Oliveira et al., 2012). To reduce the tannin content there are several techniques like leaching in cold water for several days, cooking or dehydrating them, or the easiest one that is to choose trees that already have acorns with less tannins since they keep this characteristic from one year to the next (Fonseca & Themudo-Barata, 2018).

Human consumption of acorns is a very old practice recorded through archaeological findings all over the world oak distribution area (Bainbridge, 1985). In Portugal, we have records of this consumption since the Bronze Age (Mattoso, 1993) and throughout the different periods of history (Alarcão-e-Silva, 2001; Amorim, 1987; Branco et al. 2003; Fonseca, 2004) until more recent times (Ferrão & Ferrão, 1988; Fonseca & Themudo-Barata, 2018).

Having reached the twentieth century, with the gradual improvement of populations living conditions, only moments of crisis, linked to periods of food shortage, allowed the maintenance of this habit of acorn consumption.

The period that coincided with the Spanish Civil War (1936-39) and the Second World War (1939-45) was one of crisis and famine, subjecting much of the country, namely the Alentejo, to conditions of extreme difficulty that hit with especial severity the classes of rural workers. Situations of low-income families with large offspring and nothing to eat are yet nowadays described, so each one did what he could, and this often involved robbing richer families' productions and consuming wild products, even when this meant its collection on other people's land (Fonseca & Themudo-Barata, 2018).

It is still possible to know the uses that have been made of acorns during this most difficult period. Acorns were collected in the surrounding territory of its collectors. As they are not the result of deliberate and intensive agricultural production, they have a higher nutritional value compared to nutrient intensive and extractive agricultural production. This is one of the reasons why this product maintained its nutritional value similarly to other products that were collected in the wild during this crisis period. Acorns are rich in carbohydrates, antioxidants, oleic and linoleic acids, clearly contributing to the maintenance of the health of all who consume them (Silva et al, 2016; Ferraz de Oliveira, 2012; Akcan et al. 2017).

During this period, collection, preservation and confection techniques were developed to make better use of this food and improve its characteristics and digestibility (Fonseca & Themudo-Barata, 2018).

After the Portuguese Revolution of 1974, improved living conditions led to an almost complete abandonment of this product for human consumption, which was reduced to very sporadic consumption and almost only two recipes – boiling them in water or roasting them near the fireplace embers.

Meanwhile, different environmental and social challenges, resulting from a resource exploitation model that has pushed human and natural systems to the limit, raised the need to rethink our strategies for resource exploitation and management, including resources needed for food production (FAO, 2017; De Schutter, 2010; IAASTD, 2009). Among these challenges, especially related to food and food production, we highlight climatic change, which has higher impact in the Mediterranean, causing more diseases and lower water availability, as well as lower availability of fossil fuels and other non-renewable raw materials or the growing social inequalities, reflected in the access to adequate food (IPES-Food, 2017; HLPE, 2017).

In this context, Portuguese government alongside other countries, created a set of planning tools as the Carbon Neutrality Roadmap 2050 (RNC), the National Energy and Climate Plan 2030 (PNEC) and a National Strategy for Adaptation to Climate Change (ENAAC). The ENAAC points out Agriculture, Forestry and Fisheries as one of the 9 key sectors where more can be done to avoid more emissions and to retain more carbon in the soil. According APA (2017) inventory about greenhouse gases in Portugal agriculture is responsible by about 10% of these emissions. The PNEC points out, as action plan, investing on renewable energy and on higher efficiency on its use, but this strategy has limitations and cannot be considered alone to overcome the current climate challenge.

At the same time an estimated amount of 1,3 thousand million tonnes of food suitable for human consumption is lost or wasted worldwide, annually (FAO, 2011). The estimation of the food wastage footprint carried out by FAO (2014) concluded that the costs of this food wastage correspond, annually, to 2,24 billion euros, plus 340 thousand million euros of costs to compensate damages due to the emission 3,5 gigatons of Carbon Dioxide and other gases contributing to climate change, beside costs linked to water reduction and reduced population health due to the exposure to pesticides. (FAO, 2014). In this context it is of major importance a more efficient use of the food produced, its fair distribution among population, besides a change in consumption habits through more sustainable patterns and the introduction of other alternative food sources including non-conventional edible plants (Pires, 2018).

Consumers also reflect these concerns about environmental and social challenges (Schmidt et al. 2016) leading to a resurgence of the interest in the rural, authentic and ecological consumption (Surová et al., 2014; Warrington, 2008, Tobler et al. 2011). In this sense, the consumption of products made with acorns represent thus, for their consumers, both a rescue of traditions and a support to systems recognized as sustainably managed. For producers it represents a new source of income from systems with which they often maintain a relationship that alternates between the drive of sustainable exploitation and the need to survive in a global market economy (Pinto-Correia & Azeda, 2017).

In this way, this renewed acorn consumption can represent both the emergence of sustainable production chains in response to consumers expectations about more ecological and socially responsible products, or an appropriation of these expectations by intensive and unsustainable production methods where the pursuit for profit outweighs the maintenance of more sustainable production systems.

In this article we will develop the concept of retro-innovation, describing some of its features and we will make use of acorn consumption in Portugal, in the past and in the present, to illustrate how we can use this concept in order to conceive environmental and social sustainable productive systems that respond to present and future challenges.

Theoretical framework

Retro-innovation is a concept that appeared associated with Marketing (Brown, 1999; Castellano et al., 2013; Loucanova, 2013, 2015; Amsden et al.; 2012; Chunduri, 2013; Frei, 2008; Leberecht, 2013) describing the creation of products that meet the need of consumers to use objects or live experiences from the past. The consumption of retro-innovation products is described as a consumers' search for reconnection to "something essential that appears to be missing from our modern lives" (Zack Sultan Blog, 2013), through heritage, tradition, nostalgia or revival (Castellano et al. 2016). Chunduri (2013) divides retro-innovations into three categories: the ones that authentically mimic a product or experience of the past to transport the user back into a gone era; that use a nostalgic format to meet a new need; or that use a new format to meet an old need. The underlying goal of these authors is to find new ways to promote economic growth or to understand why not always more technology leads to more sales. Bravo (2019) uses the concept of retro-innovation as a way of food companies seek for quality and healthiness in the innovation for sustainability framework. Stuiver (2006) highlight the potential of retro-innovation or "the retro side of innovation" to develop viable alternatives for rural development using a Strategic Niche Management approach. This author describes retro-innovation as "developing knowledge and expertise that combines elements and practices from the past (from below modernization) and the present and configures these elements for new and future purposes". She highlighting its role as an alternative to current development regimes focused on achieving more productivity, efficiency, and export-oriented agriculture in an increasingly globalized and liberalized world, which requires farms of increasing size, specialization and intensification levels. Stuiver also draws attention to the role of research as facilitator of retro-innovation by producers.

In this paper we propose that retro-innovation can be considered as a way of adapting consumption habits towards better resources' allocation, expected to be scarce in the future, such as fossil fuels, water or non-renewable raw materials as well as to a more equal distribution among its potential users. Retro-innovation can thus contribute to a low carbon economy, in order to deal with Climatic Change and the growing social inequalities.

This proposal is based on the fact that products and techniques developed in certain periods of our history result from resource-constrained environments, as the ones created before the wide use of fossil-fuels, the easy access to non-renewable inputs, the vulgarization of irrigation systems and the widespread dissemination of a market economy. These resource-constrained innovations can refer not only to tools or technical devices, but also to production processes, resources used (Fonseca & Themudo 2018) or even to governance practices linked to the use of these resources (Antunes 2015; Dias 1983, 1984). They were, as described by Pisoni (Pisoni et al. 2018) frugal innovations, that can be adapted nowadays to more sustainable practices and consumption.

The European Union has proposed in its Policy Brief (2014) on research and innovation to address major global challenges, that frugal innovation should also be considered in more advanced economies, in addition to the traditional focus on less developed economies.

Retro-innovation has, in this sense, the following characteristics:

- Use, as basis for innovation, the ancient knowledge about products use, processes as well about their distribution among their potential users, developed before the widespread availability of fossils fuels and the ensuing dominant modernization project;

- Usually it is still possible to find a body of knowledge about tools, processes and management practices, linked to resources use;
- It is territorialised in the sense that linked to the territories were the previous technologies were developed, namely cultural and biophysical characteristics;
- It can be implemented in developing but also developed economies, once ancient knowledge does not obey to the current distributions of wealth according to which we distinguish developed from underdeveloped countries;
- Because it is based on traditional practices and local resources it has a high potential for acceptance by both local users and visitors, contributing to the reinforcement of the identity of each region;
- It was developed by local population, without scientific and inaccessible knowledge for its design, resulting in appropriate technology instead of high tech, thus being capable of re-appropriation by a wider range of users;
- Once the ancient knowledge was often consolidated in periods of scarcity of resources, it has the potential to offer products and processes that make low use of non-renewable energy and raw material and to developing deficit watering systems.

2. Methods:

To illustrate the potential contribution of retro-innovation to deal with the global challenges we face, we focus on acorn use in Portugal throughout history.

Our approach to acorn consumption was dived in two main periods (Table 1): A - in the twentieth century and B - in the twenty-first century until nowadays. Data collection followed different procedures according to the period studied. For period A a literature review was conducted as well as semi-structured interview (Annex A) to 20 respondents of an intentional sample, usually but not always, users of retirement homes, of Montemor-o-Novo and Évora municipalities from Alentejo region, besides a key informant, part of one of these retirement homes. These interviews were recorded, transcribed and numbered. Respondents were asked to name of the wild products they consumed, excluding medicinal and aromatic plants and cultivated products. This information was supplemented with some bibliography that addresses the same period and the same region. For period B, on the actual use of acorn as food for humans, a questionnaire (Annex B) was made to the main companies identified as processing acorns today. From the eight companies identified only seven managed to get the data requested. These companies where identified with a number to maintain anonymity. For the later, the questionnaire was replaced by an interview that allowed a more detailed description of the current situation regarding the acorn row in Portugal.

Table 1 – Approaches according each period studied.

	Period A	Period B
Corresponding period	in the twentieth century	in the twenty-first century until nowadays
Methods	• literature review, • 21 semi-structured interviews (Annex A)	• Questionnaires to eight companies processing acorns (Annex B)
References	Fonseca & Themudo 2018	

Data collected for period A comprised other products besides acorns and were divided by collection, storage and confection methods, besides the confection of animal feed. Living conditions and political conjuncture were also described in order to understand the reasons underlying the consumption of wild food products in this period. The questionnaires used to evaluate the recent evolution of new companies based on acorn processing (Period B) were sent by e-mail, after a contact by phone or personally. One of these companies did not answered by lack of data, but a later contact by phone allowed to add enriching aspects to data obtained from the questionnaires.

3. Results:

3.1 Acorn use in the twentieth century

From the interviews we realize that people in Alentejo used to distinguish several varieties of holm oak acorns: the long and short *bical*, the normal acorn and the *castanhola*[50]. However, although *castanholas* are the most appreciated, they are also relatively rare and, according to Salgueiro, are sparsely distributed among the other varieties of holm oaks.

Acorns quality remains constant from one year to the other, so shepherds and country people were aware of the oaks that gave good acorns. Another strategy was to taste the acorns of a tree: if some were of good quality, all others would be too, according Salgueiro (2005): “We always tasted the acorns before we caught them.” Or as one woman describes in Fonseca (2007): “I ran ahead of the pigs that were grazing around the school to steal their sweet acorns from the ground, which served as bread coverage.”

Salgueiro (2005) describes: “My mother used to send me with my sister to fetch them and each one brought a basket full of them. By the end of the day, there was a huge amount at home, enough for several days. We got them because the guards didn't care about the kids. If my mother or father would catch them, the guard would report to the authorities immediately.”

But not all *Montado* owners had this position with regard to the poor who came to catch acorns on their farms. Some lived better with this recollection, as it was the case of Herdade do Freixo do Meio owner, Alfredo Maria da Praça Cunhal as described by Salgueiro (2017): “(…) In that estate of Freixo there was a lot of acorn. (...) My uncle and my father were going to fill the bags at night. See, from Gafanhão[51] to Freixo, by foot until Foros Vale de Figueira[52], the distance that it was. By foot, those two souls were carrying bags full of acorns. (...) Those souls came with those bags full of acorns, they came here, they went to sell to the Maia[53] area, to the farmers, to men who had pigs in sties, to gain weight.”

These were the “*boleteiros*[54]” described by Silva Picão (1903) as those men who, at the season of acorns, invaded the others’ *Montados* collecting large amounts of acorn and then selling it as their own. Silva Picão also describes that these “*boleteiros*” would be unemployed rural workers or *Malteses*[55]. This acorn would be used for its own food or for sale. This was an institutionalized

[50] *Castanhola* comes from *castanha*, the Portuguese name to chestnut, because these acorns are the most similar to chestnuts, both in shape and taste.
[51] At 1 Km from Montemor-o-Novo
[52] At 12 Km from Montemor-o-Novo
[53] 3 km from Montemor-o-Novo
[54] *Boleteiros* from the Portuguese word for acorn – *bolota*. So, men that pick-up acorns.
[55] People without fixed residence or employment who moved around the territory and lived on what they stole or from small temporary activities.

robbery, to which some owners closed their eyes, because they knew the situation of need to which Alentejo workers were subjected (Cutileiro, 1977).

But as Madureira (2002) points out, this acorn gathering activity was also part of the temporary farming activities carried out mainly by women and young people who were hired to catch acorns that fell from the trees and were then bagged to be given to pigs during periods when they did not exist in the *Montados*. Frequently these collected acorns were stored in anoxic water tanks in order to lose tannins and to last longer. Examples of this are the large tanks belonging to the Praça family in Montemor-o-Novo, which, although they no longer perform this function, still retain their original structure.

Often the activities of keeping pigs and collecting acorns were connected, the first being carried out by children at the beginning of their working life in agriculture, as Madureira (2002) points out. Later these same pig keepers were “hired, as was the case in Palma, to pick-up acorns that fell from the holm oaks to be bagged and kept to feed the pigs in the winter.”

Some of the interviewees (E1, E4) describe how women walked in groups picking acorns among cereal crops that stretched beneath the holm oaks canopy. The acorns were later bagged and used to feed the enclosed animals.

Often, they were consumed raw, but they were also, often cooked and baked among the ashes of the hearth, as they were preferred. In both cases it was necessary to shred them so they wouldn't explode in the fireplace or cook better in the pan. Salgueiro describes how they go well with lemon bark, melissa, cinnamon or even with fennel and salt (E1).

There were techniques for storing acorns to serve as food for the rest of the year (E4). With this purpose they were *aveladas*[56], that is, dried with the shell in dry places and turned frequently, in order to avoid the humidity and the resulting mold. After a few weeks they withered, lost moisture, but became sweeter and softer, losing some of the tannins they still had. They were then stored in wooden chests and lasted the rest of the year, becoming tasty and keeping some moisture. Guarantees who proved, (E4) that they were very good. Another technique, (E4) which further ensured better preservation and flavour was to bake the acorns lightly, peel and smoke them in the fireplace chimney, in baskets made of olive branches, for at least two weeks (E9).

In the municipality of Montemor-o-Novo some of the interviewees talk of cooking acorns with sprouts (E2), acorns with honey (E4), acorn marmalade (E4), rice cooked with dehydrated acorns, served by Easter (E4, E19), chickpea pastry made with acorns (E19), and other specialties whose recipes, for lack of continuity, have been lost. As noted by Salgueiro (2005) “Still the roasted and milled acorns make a good coffee, healthier than the other.”

Another use given to acorn was its transformation into oil and animal feed. The Évora processing unit worked between 1967 and 1979 and transformed about 250 Ton of acorns per day during the acorn campaign, according to its manager. Acorns were transformed into pure acorn or mixed oil for human consumption, and acorn flour that was sold to another factory to mix with other products to prepare animal feed. The rise in labor prices led to its end and the closure of the structures used in this transformation.

[56] From the portuguese word *avelã* - hazelnut, because they ended up with a taste similar to that of this fruit.

3.2 The period of abandonment of acorn consumption

However, in the post-revolution period, the living conditions of rural populations improved. Acorn consumption has been virtually abandoned, limited to a very sporadic consumption of roasted acorns.

The amount paid for labour has increased substantially, making some of the practices described above unfeasible, such as hand picking of acorns from sown fields, to preserve them in anoxia in farm ponds and feed animals later or hand picking of acorns from the fields, usually to sell to farm owners, or to sell to the acorn oil factory.

3.3 The resurgence of acorn use

The support of Portuguese Innovation Agency to the introduction of a master in an organic farm in Montemor-o-Novo, through a grant whose goal was developing acorn-based products, lead to the first of these products in the market in 2008. From the seven companies interviewed, two started acorn processing on 2014, two in 2016, and the latter two in 2017. Other small experiences, in a pre-entrepreneurial phase, are distributed a little throughout the country, but whose activity is developed irregularly and with very low incomes.

As a result of this increase in the number of companies, the development of new products and their consolidation in the market, the overall use of acorns has increased from 50 kg in 2008 to 6730 kg, ten years later. However, the pioneer in this transformation continues processing 74% of the acorn, transformed by these companies, followed, with a great distance, by one of the newest companies that processes 10% of all the acorns and another older one that processes 9%. The rising on acorn processing was not uniform. A significant increase in the amount of acorn processed from 100% or below this value, of annual growth in the first years to a sudden increase of 319% in 2015, corresponding essentially to the growth in this transformation by the pioneer company 4, which alone is responsible for 500% of acceleration of this activity in the same year. In the following years, the acorn processing activity continued to increase, but more slowly.

Only companies 1, 3 and 7 sell their products to other European countries. While for company 1 this is a growing strategy that started with 20%, to 30% and 35% in 2016, 2017 and 2018 respectively, and for company 2 corresponds to 30% in the two last years, the later, company 7 exported 90% of its production in 2018. Even company 8 had a large order for the Netherlands, which at the time was unable to answer because the lack of acorn flour.

Income providing from this processing also increased in the same order from 50 € to 16 770 € with company 4 earning 38% of the total income with this activity in the group of companies, followed by company 1, with 38% and company 2 that earned 32% of the income with acorn-based products. This company 2 corresponds to a special case because it is quite new, starting its activity only on 2017 but processing, already in this year the same quantity than company 4, the pioneer company, corresponding to 4000 Kg. On 2018 company 2 processed 8000 Kg of acorns against the 4458 Kg processed by company 4.

With regard to the yield obtained with the acorn products, values range from 0.93 €/kg in company 4 to values of around 40 €/kg in company 5 or 13 €/kg in company 7. These values correspond to different selling strategies ranging from company 4 that invests clearly in the production and sale of acorns with low processing levels (shelled acorn or acorn flour) to provide other companies and individuals for further processing, to companies that sell high value-added products like acorn bonbons or acorn buttercream.

The products created by the eight companies are presented below in Table 1.

1	Fresh whole acorns
2	Frozen whole acorns
3	Peeled and dried holm oak acorns
4	Peeled holm oak acorn flour
5	Toasted flour for infusion
6	Toasted flour for coffee
7	Toasted flour for infusion, in single sachets
8	Acorn milk
9	Acorn buttercream
10	Acorn and carob buttercream
11	Acorn and lavender buttercream
12	Acorn and thyme buttercream
13	Organic acorn jam
14	Organic acorn and peppermint jam
15	Chocolate candies stuffed with acorn flour
16	Cookies with seven different flavours including one vegan, one without wheat and one special for diabetics
17	Bread with sweet and salty stuffing
18	Bread
19	Cornbread
20	Toasts
21	Biscuits
22	Salty pate
23	Soup
24	Hamburgers
25	Acorn meatballs
26	Acorn delights
27	Acorn cream pastry
28	Chocolate tablet with acorn
29	Acorn cupcake
30	Acorn sugar
31	Yogurt

Some of these products are regularly sold while others constitute more punctual experiences. One of such cases is acorn sugar, for which an enzyme must be used and is therefore, according the company owner, a more sophisticated process and in need of efficiency improvements in the production process.

3.4 The demand for innovation

A global trend of these products has been the improvement of their characteristics. According to the owner of company 8, acorn flour he uses has more constant and reliable characteristics, allowing the establishment by this processor of a fixed recipe, without the need for constant adaptations. As he explained, this has to do with the dehydration process of acorns in the supplier company, company 4, that is now slower but more uniform, allowing to obtain a fine and uniform flour.

As explained before, company 4 was the first one starting acorn processing. The owner explained that in 2015 they decided to take acorn industry more seriously. Several methods have been tested then, namely those already developed for olive harvesting, such as vibrators or sticks with motor. They also tested acorn aspiration from the ground using vacuum cleaners and sweepers. Later on, they decide to pay to pickers and actually, the model is to pay, a little bit more, to two pickers by already chosen acorns, without visible insect holes and separated between holm oak and cork oak acorns.

Shelling and conservation of flour and acorns also presented problems in need of solution. The first solution was to freeze the acorns right after picking and send them to a chestnut processing factory in the north of the country. Here acorns where subjected to a thermal shock, in addition to eliminating the fruits affected by insects or already rotten using an optical eye. This process included the peeling of acorns and totally eliminated the tannins. This latter characteristic proved to be negative as the tannins allow conserve the flour, this without tannins degraded very rapidly, leading to high losses. This solution has proven, also, to be extremely costly being replaced by the current solution. After realizing that it would be easy to peel the acorns if they were dried, the next step was to recreate the old smoking process over a board made of canes. Thus, a temperature-controlled oven was built which, instead of roasting the acorns, dried them. The bark is thus more easily removed and the tannins, preserved, resulting in products with a longer shelf life, more uniform characteristics and a large reduction in production costs.

Although a path has already been made, in company 4, in the innovation process around acorn processing, other needs are still pointed out by the owner. Namely tree harvesting equipment adapted to a more fragile tree in relation to olive trees, equipment to collect acorns from the ground. However, the owner acknowledges that the current model of buying acorns from pickers is less aggressive to the trees, more socially responsible and allows to keep noisy machinery out of a system characterized by silence and tranquillity.

Acorn sugar is produced though a process similar to the one used with corn starch in the production of corn jelly and sugar, but industrialization is pointed as a solution for its viability as it requires its own large equipment that is difficult for small companies to own.

A set of chain companies, is the solution also pointed out by this owner, to get the most out of acorn. Thus, in a circular economy logic, an acorn oil extraction plant would be followed by an acorn sugar extraction company and finally one for the incorporation of acorn flour into animal feed, replicating what has already been done in the 1970s in this region.

An acorn yogurt and industrial cookies were also been tested, but its viability has been compromised, in both cases, by lack of product.

In order to reinforce innovation in this sector, company 4 has been in regular contact with several academic and industry institutions.

The owner of this company concludes by explaining that despite processing around 5 ton per year, he could process until 200 ton, and that a producer organization around this product would allow to produce a lot of food for many people.

Some products require higher technology then other. Between this one can include acorn milk, that tends to be a very suitable medium for the proliferation of microorganisms, so it requires a pasteurization process that does not degrade the remaining qualities of the product. This implies hi-technology devices.

3.5 Hi and low tech

According Khalil (2018), technology is a word that comprises the materials, systems and construction methods, and that may be implemented at a higher or lower level. In this sense, low-tech is defined, by opposition to high tech, as making use of simpler technologies, being more easily used and adapted by individuals or small groups with basic knowledge. Instead, high-tech makes use of all the available modern potentials, through the implementation of advanced procedures, requiring experts to its construction, use, maintenance and adaptation (Khali et al., 2018). Table 2 summarizes the key features of these two types of technology.

Table 2 - Key features of Low and High technologies.

		Low-tech	High-tech
1	Complexity of technology	Simple	More complex
2	Knowledge used	Lower and traditional knowledge	Intensive experts' knowledge
3	Link to tradition	Strong but not always	Barely
4	Investment of capital	Low	High
5	Users	Individuals or small groups	Large groups
6	Strategies	Passive systems	Active systems
7	Methods	Simple	Complex
8	Energy requirements	Low	High
9	Crossed-compatibility	Yes	Yes
10	Resources use:		
	Provenance	Local	Global
	Quantity required	Low	High
	Availability	Easily available	Restricted, with need of extraction and purification
	Quality	Any	High
	Transport distance	Short	Long
11	Final product quality	Adequate	High
12	Available to modification or adaptation by users	Easily	Barely
13	Maintenance	Easy at low price	Difficult and costly

During period A it is possible to identify a set of older or newer technologies. While its majority are of the low-tech type, some can be considered as being high-tech.

Low-tech:

- Knowledge of trees that give the sweetest acorns
- Acorn picking by hand
- Selection by hand of acorns without holes and between holm oak and cork oak acorns
- Conservation to human consumption making use of the tannins naturally present in acorns by slow drying in aerated places and turning acorns frequently, in order to avoid the humidity and the resulting mold

- Conservation, to feed the animals out of acorns season, in anoxic water tanks with salt in order to lose tannins and last longer
- Several recipes requiring an oven or fireplace, honey and other ingredients locally available
- Acorns broken with a heavy rock to feed poultry

High-tech:

- Acorn oil extraction plant
- Animal feed, out of acorns season, with rations including acorn waste resulting from acorn oil factory

During period B, we identify several technologies, to treat acorns that can be integrated into hi and low-tech.

Low-tech:

- Acorn picking by hand
- Selection by hand of acorns without holes and between holm oak and cork oak acorns
- Conservation using tannins naturally present in acorns
- Acorns drought using a traditional smoking process in a temperature-controlled firewood oven
- Shelling by compression of dried acorns

High-tech:

- Tree vibrators for acorns harvesting
- Sticks with motor for acorns harvesting
- Vacuum cleaners for acorn aspiration
- Sweepers to gather the acorns and facilitate the collection
- Shelling and conservation by thermal shock in a chestnut processing factory
- Selection of healthy acorns using an optical eye
- Enzymatic process to produce acorn sugar
- Industrial cookies
- Yogurt manufacturing
- Pasteurized acorn milk (Sardão et al. 2019)

Meanwhile we take notice of other practices such as acorn production in super intensive holm oak plantations to feed black pigs in captivity.

4. Discussion

Through the data previously exposed we can realize that acorn consumption has been a constant throughout the history of Portugal.

It was identified also a recent interest in the use of this product and the recovery of some recipes, materialized in a set of acorn processing companies that have appeared in Portugal. The reasons behind this renewed interest are several, according the different actors in the value chain. Producers seek mainly income diversification, while consumers have, as main drivers, the link with tradition, health and the opportunity to consume products providing from systems acknowledged as sustainable.

In addition to these drivers, both globally and in Portugal, we face new challenges such as climate change and resource depletion that require adaptation and minimization measures (APA, 2015; APA 2019). The need for developing decarbonisation measures is difficult to match with the need to produce food for a growing population. However, it is recognized that a large part of the problem lies more in an adequate distribution of available production and in increasing the quality of food produced than in simply increasing the quantity produced.

The development of sustainable food production systems can be one way of combining food production with environmental preservation. Wild foods as acorns are an excellent opportunity in this context once they require less water, plant protection drugs, or fossil fuels to agricultural works. In their quest for innovation to address different problems related to the acorn transformation process, small and medium-sized businesses tend to make use of low-tech or appropriate technology practices, often adapted from older practices in a retro-innovation process. Processes involving more sophisticated technologies such as pasteurization, the manufacture of acorn oil or sugar through an enzymatic process are only accessible to larger companies that process large amounts of acorns, thus requiring an intensification degree that is hardly compatible with the sustainable exploitation of an extensive system such as the Montado or the oak forests of northern Portugal.

Accompanying the growth in the acorn processing sector, non-sustainable productive systems appears, as acorn production in super-intensive holm oak irrigated plantations.

As Winner (1985) refers, the beginning of technology establishment is when there is more freedom of choice about what kind of technology will be adopt in a sector. As certain choices are made in one direction or another, between more complex or simpler technologies, between the possibility of they being appropriated by all or only by a restricted group of great transformers, initial freedom is restricted and only with much difficulty the paths chosen can be reversed.

In what refers to the acorn sector, this is the perfect time to think about the kind of production we want to promote: one that meets consumer expectations of sustainable consumption or a business-as-usual model, with the consequences we all know.

Attention should be paid to ensure that, in the path of retro-innovation, the sustainability of ancient practices and the arguments that may underpin consumer preferences are not lost. In order to maintain their sustainability, certain aspects of the innovation of these products must be monitored, such as the expenditure of energy and raw materials in the manufacture of new products, the maintenance of a sufficient level of technology to enable innovations to be appropriated and disseminated by others, the distance between the place of production and processing, the processing methods, the destination of the waste from this processing.

This sustainable retro-innovation may be of interest not only in the case of acorn, but also for so many products under the name of wild edible foods, or underused crops, whose recovery has increasingly been a goal of different scientific entities. In these cases, too, it is important to consider what kind of food sectors we want to develop, what goals we want to serve: a sophisticated industrialization process, highly resource demanding and that can only be understood and managed by a small profit-earning elite, or a lower-tech and low-resource demanding process that allows broader income distribution for larger fringe of the population while responding to the major environmental challenges we face?

As Pansera argues (2013, 2018) frugal innovation *per se* is not enough to solve environmental and social problems. This must be embedded in social and institutional eco-innovation. Also, in this aspect, retro-innovation can provide a contribution for developing new social arrangements based on ancient practices around work distribution, collective activities or adequate technology that allows a more democratic appropriation of innovation.

4. References

Acácio, V.; Dias, F.; Catry, F.; Rocha, M.; Moreira, F. (2017) Landscape dynamics in Mediterranean oak forests under global change: understanding the role of anthropogenic and environmental drivers across forest types. Global Change Biology (2017) 23, 1199–1217, doi: 10.1111/gcb.13487

Almeida, M.; Guerra, C.; Pinto-Correia, T. (2013) Unfolding relations between land cover and farm management: high nature value assessment in complex silvo-pastoral systems. Geogr. Tidsskr.-Danish J. Geogr. 113 (2), 97–108. https://doi.org/10.1080/00167223.2013.848611.

Antunes, M.A (2015) Vilarinho da Furna: Um projeto museológico de turismo sustentável.

Agência Portuguesa do Ambiente (APA), «Portuguese national inventory report on greenhouse gases, 1990-2015», May 2017, www.apambiente.pt/_zdata/Inventario/2017/20170530/NIRglobal20170526.pdf.

Agência Portuguesa do Ambiente (2019) Roteiro para a Neutralidade Carbónica (RNC 2050) (Carbon Neutrality Roadmap). Accessed on https://descarbonizar2050.pt/

Akcan, T.; Gökçe, R.; Asensio, M.; Estévez, M.; Morcuende, D (2017) Acorn (Quercus spp.) as a novel source of oleic acid and tocopherols for livestock and humans: discrimination of elected species from Mediterranean forest. Journal of Food Science and Technology - Mysore- 54(10):1-8 DOI: 10.1007/s13197-017-2740-3

Amsden, B.; Guldbrandsen, T.; Okrant, M. (2012) Reinventing 'retrotels': using engaged scholarship to market nostalgia tourism in rural New Hampshire. Proceedings of the 2010 Northeastern Recreation Research Symposium, GTR-NRS-P-94, pp. 257-261.

Bainbridge, D.A. (1985) Acorns as food: oak bibliography No. 1, with an introduction, country use list, and nutrient analysis. Twain Harte, California: Sierra Nature Prints.

Baud, I. (2016) Moving Towards Inclusive Development? Recent Views on Inequalities, Frugal Innovations, Urban Geo-Technologies, Gender and Hybrid Governance. The European Journal of Development Research, 28(2): 119-129.

Bingre, P.; Aguiar, C.; Espírito Santo, D.; Arsénio, P.; & Monteiro-Henriques, T. (2007) Guia de campo: árvores e arbustos de Portugal Continental. Jornal Público, Fundação Luso-Americana para o Desenvolvimento/Liga para a Protecção da Natureza.

Branco, M.; Bragança, H.; Sousa, E.; Phillips, A. (2014) Pests and Diseases in Portuguese Forestry: Current and New Threats. F. Reboredo (ed.), Forest Context and Policies in Portugal, World Forests 19, 5: 117-154. DOI 10.1007/978-3-319-08455-8_5

Bravo, V.L.; Moretto, A.; Cagliano, R.; Caniato, F. (2019) Innovation for sustainable development in the food industry: Retro and forward-looking innovation approaches to improve quality and healthiness. Corporate Social Responsibility and Environmental Management 26(4) DOI: 10.1002/csr.1785

Brown, S. (1999) Retro-marketing: yesterday's tomorrows, today! Marketing Intelligence and Planning, Vol. 17 No. 7, pp. 363-376.

Bugalho, M.; Plieninger, T.; Aronson, J.; Ellatifi, M.; Crespo, D.G. (2009) Open woodlands: A diversity of uses (and overuses). In: Aronson, J., Pereira, J.S., Pausas, J.G. (Eds.), Cork Oak Woodlands on the Edge. Ecology, Adaptive Management, and Restoration. Island Press, Washington, pp. 33–45.

Camilo-Alves, C.S.; da Clara, M.I.E.; Ribeiro, N.M.C.A. (2013) Decline of Mediterranean oak trees and its association with Phytophthora cinnamomi: a review. Eur. J. For. Res. 132, 411–432. https://doi.org/10.1007/s10342-013-0688-z.

Camilo-Alves, C.S.; Vaz, M.; da Clara, M.I.E.; Ribeiro, N.M.C.A. (2017) Chronic cork oak decline and water status: new insights. New For. 48, 753–772. https://doi.org/10.1007/s11056-017-9595-3

Castellano, S.; Ivanova, O.; Maâlaoui, A.; Safraou, I.; Schiavone, F. (2013) Back to the Future: Adoption and Diffusion of Innovation in Retro Industries. European Journal of Innovation Management. Vol. 16 No. 4, 2013. pp. 385-404. DOI: 10.1108/EJIM-03-2013-0025

Castro, M.; Castro, J.; Sal, A.G. (2009) Efeito da Pastorícia Tradicional na Redução de Combustíveis Finos em Bosques de Quercus pyrenaica. Silva Lusitana 17(2): 159 - 169, 2009

Castro, M.; Hassidou, M.; Castro, J.F (2017) Preferencia y selectividad del paisaje por rebaños de ovinos y caprinos en el nordeste de Portugal. 7º Congreso Españole Gestión del monte: servicios ambientales y bioeconomía. Sociedade Española de Ciencias Forestales. ISBN 978-84-941695-2-6

Chunduri, C.H. (2013) Marketing Nostalgia - Retro Innovation (on-line) https://medium.com/noise-branded/b542fbbe406e Accessed 09.10.2019

Costa, A., Madeira, M., Santos, J. L., & Oliveira, Â. (2011). Change and dynamics in Mediterranean evergreen oak woodlands landscapes of Southwestern Iberian Peninsula. Landscape and Urban Planning, 102(3), 164-176.

De Schutter, O. (2010) Agroecology and the Right to Food. Report presented to the Human Rights Council 8. A/HRC/16/49, Sixteenth Session. New York, USA, United Nations.

Dias, J. (1983) Vilarinho da Furna: uma aldeia comunitária. Imprensa Nacional Casa da Moeda

Dias, J. (1984) Rio d'Onôr: Comunitarismo agropastoril. Editora Presença

Estratégia Nacional de Adaptação às Alterações Climáticas (ENAAC 2020) - Resolução do Conselho de Ministros n.º 24/2010., in Diário da República, 1.ª série — N.º 64 — 1 de Abril de 2010. Accessed on 16-10-2019 at https://dre.pt/application/dir/pdf1sdip/2010/04/06400/0109001106.pdf.

European Commission (2008) Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan.

European Commission (2014) The International Dimension of Research and Innovation Cooperation Addressing the Grand Challenges in the Global Context. Final Policy Brief. Prepared for the European Commission Directorate General for Research and Innovation.

FAO (2011) Global food losses and food waste. Food and Agriculture Organization of the United Nations; Rome

FAO (2014) Food Wastage Footprint, Full-Cost Accounting, final report. Food and Agriculture Organization of the United Nations; Rome.

FAO (2017) The future of food and agriculture: Trends and challenges. Food and Agriculture Organization of the United Nations; Rome.

Ferrão, J.E.; Ferrão, A.M.B.C. (1988). A bolota e a glande, potencialidades em óleo e farinha, Revista de Ciências Agrárias, 2, 15-29.

Ferraz de Oliveira, M.I.; Machado, M.; Cancela d'Abreu, M. (2012) Acorn chemical composition depending on shedding date and Quercus species. In: De Pedro E.J. (ed.), Cabezas A.B. (ed.). 7th International Symposium on the Mediterranean Pig. Zaragoza : CIHEAM, p. 229-234 (Options Méditerranéennes: Série A. Séminaires Méditerranéens; n. 101)

Fonseca, M.T. (2007). A Memória das Mulheres - Montemor-o-Novo em tempo de ditadura. Edições Colibri.

Frei, B. (2008) Why retro innovation is the most lucrative kind (on-line) https://venturebeat.com/2008/04/21/why-retro-innovation-is-the-most-lucrative-kind/ Accessed 09.10.2019

Gea-Izquierdo, G.; Cañellas, I.; Montero, G.; (2006) Acorn production in Spanish holm oak woodlands, In Investigación agraria: Sistemas y recursos forestales. 15: 339-354

Guiomar, N.; Godinho, S.; Fernandes, P.M.; Machado, R.; Neves, N.; Fernandes, J.P. (2015) Wildfire patterns and landscape changes in Mediterranean oak woodlands. Sci.Total Environ. 536, 338–352. https://doi.org/10.1016/j.scitotenv.2015.07.087.

Godinho, S., Guiomar, N., Machado, R., Santos, P., Sá-Sousa, P., Fernandes, J. P., ... & Pinto-Correia, T. (2016). Assessment of environment, land management, and spatial variables on recent changes in montado land cover in southern Portugal. Agroforestry systems, 90(1), 177-192.

Gómez-Sal, A. (2000) Las razas de ganado autóctono en la conservación de la naturaleza. In: Rodríguez F (ed) Manual del técnico en medio ambiente natural. Colegio de Veterinarios de Ourense, Ourense, Spain

Gioia, D. A.; Corley, K. G.; Hamilton, A. L. (2012) Seeking Qualitative Rigor in Inductive Research: Notes on the Gioia Methodology. Organizational Research Methods, 16(1), 15–31. https://doi.org/10.1177/1094428112452151

Gustavsson, J.; Cederberg, C.; Sonesson, R.; van Otterdijk, R.; Meybeck, A. (2011) Global foodlosses and food wastes: extent, cause and prevention. Office of Knowledge Exchange, Research and Extension, FAO, Italy. Rome.

HLPE (2017) Sustainable forestry for food security and nutrition. A report by the High-Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security, Rome.

IAASTD (2009) Agriculture at a Crossroads. International Assessment of Agricultural Knowledge, Science and Technology for Development Global Report. Island Press, Washington, D.C.

Instituto da Conservação da Natureza e das Florestas, I. P. (2016) Espécies arbóreas indígenas em Portugal continental - Guia de utilização Instituto da Conservação da Natureza e das Florestas, I. P. Departamento de Gestão e Produção Florestal

IPCC (2014) Climate Change 2014: Synthesis Report. Summary for Policymakers. Fifth assessment report. Cambridge University Press, Cambridge, United Kingdom

IPES-Food (2017) Unravelling the Food–Health Nexus: Addressing practices, political economy, and power relations to build healthier food systems. The Global Alliance for the Future of Food and IPES-Food.

James E. Rowe Controversies in Local Economic Development: Stories, Strategies, Solutions – By Martin Perry, March 2011Regional Science Policy & Practice 3(1). DOI: 10.1111/j.1757-7802.2010.01025.x

Jänicke, M. (2008) Journal of Cleaner Production. Volume 16, Issue 5, March 2008, Pages 557-565. Journal of Cleaner Production. Ecological modernisation: new perspectives. https://doi.org/10.1016/j.jclepro.2007.02.011

Knorringa, P.; Peša, I.; Leliveld, A.; Van Beers, C. (2016) Frugal Innovation and Development: Aides or Adversaries? The European Journal of Development Research, 28(2): 143-153.

Leberecht, T. (2013) Back To The Future: Why Retro-Innovation Is The Next Big Thing (on-line) http://www.fastcodesign.com/1672508/back-to-the-future-whyretro-innovation-is-the-next-big-thing Accessed 09.10.2019

Loucanova (2013) Retro-innovation versus family life cycle as a predictor of behaviour. Intercathedra. Vol 29, Issue: 3: 48-52. YADDA identifier: bwmeta1.element.agro-d16ef2c9-dc07-466d-9a54-1072d11f3154

Loucanova, E.; Parobek, J.; Kalamarova, M. Studia (2015) Retro-innovation and corporate social responsibility. Universitatis "Vasile Goldis" Arad. Economics Series Vol 25 Issue 4. Pages 1 – 11. ISSN 1584-2339. Web: publicatii.uvvg.ro/index.php/studiaeconomia.

Madureira, N. L. (2002). História do Trabalho e das Ocupações. Vol.III – A Agricultura: Dicionários das Ocupações. Celta Editora

MASON, S. R. L. 1995: Acornutopia? Determining the role of acorns in past human subsistence. In: Wilkins, J., Harvey, D., Dobson, M. (Eds.): Food in Antiquity. University of Exeter Press, Exter, 12–24

Mosquera-Losada, M. R.; Moreno, G.; Pardini, A.; McAdam, J. H.; Papanastasis, V.; Burgess, P. J.; Lamersdorf, N.; Castro, M.; Liagre, F.; Rigueiro-Rodríguez, A. (2012) Past, Present and Future of Agroforestry Systems in Europe. P.K.R. Nair and D. Garrity (eds.), Agroforestry - The Future of Global 285 Land Use, Advances in Agroforestry 9, DOI 10.1007/978-94-007-4676-3_16, 285-312.

Nieto Quintano, P.; Caudullo, G.; de Rigo, D. (2016) Quercus pyrenaica in Europe: distribution, habitat, usage and threats. In: San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., Mauri, A. (Eds.), European Atlas of Forest Tree Species. Publ. Off. EU, Luxembourg, pp. e01f807+

Ostrom, E. (1990) Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge, UK: Cambridge University Press.

Pacheco, A.R (2015) Análise nutricional, físico-química e atividade antioxidante de frutos de Quercus sp. visando a sua valorização. Dissertação do 2º Ciclo de Estudos Conducente ao Grau de Mestre em Controlo da Qualidade Especialidade em Água e Alimentos. Faculdade de Farmácia. Universidade do Porto.

Pais, J. (1996). Paleoetnobotânica (Finais séc. XI a séc. XIII/XIV) do sul de Portugal – Setúbal, Mértola e Silves in Arqueologia Medieval. pp. 277 – 282. nº4. Edições Afrontamento.

Pansera, M. (2013) Frugality, Grassroots and Inclusiveness: New Challenges for Mainstream Innovation Theories. Pp. 469-478. https://doi.org/10.1080/20421338.2013.820445

Pansera, M. (2018) Frugal or fair? The unfulfilled promises of frugal innovation. Technol. Innov. Manage. Rev. 8(4), 6–13

Pinto-Correia, T.; Azeda, C. (2017) Public policies creating tensions in Montado management models: Insights from farmers' representations. Land Use Policy 64, 76–82. https://doi.org/10.1016/j.landusepol.2017.02.029.

Pinto-Correia, T., Ribeiro, N., Sá-Sousa, P., (2011) Introducing the montado, the cork and holm oak agroforestry system of Southern Portugal. Agrofor. Syst. 82, 99–104. https://doi.org/10.1007/s10457-011-9388-1.

Pinto-Correia, T., & Godinho, S. (2013). Chapter 4 Changing Agriculture–Changing Landscapes: What is Going on in the High Valued Montado. In Agriculture in Mediterranean Europe: Between old and new paradigms (pp. 75-90). Emerald Group Publishing Limited.

Pinto-Correia, T.; Guiomar, N.; Ferraz-de-Oliveira, M.I.; Sales-Baptista, E.; Rabaça, J.; Godinho, C.; Ribeiro, N.; Sá-Sousa, P.; Santos, P.; Santos-Silva, C.; Simões, M.P.; Belo, A.D.F.; Catarino, L.; Costa, P.; Fonseca, E.; Godinho, S.; Azeda, C.; Almeida, M.; Gomes, L.; Lopes-de-Castro, J.; Louro, R.; Silvestre, M.; Vaz, M. (2018) Progress in identifying high nature value montados: impacts of grazing on hardwood rangeland biodiversity. Rangel. Ecol. Manag. 71, 612–625. https://doi.org/10.1016/j.rama. 2018.01.004.

Pires, I. (2018) Desperdício Alimentar. Ensaios da Fundação. Fundação Francisco Manuel dos Santos.

Pisoni, A., Michelini, L., & Martignoni, G. (2018) Frugal Approach to Innovation: State of the Art and Future Perspectives. Journal of Cleaner Production, 171(10): 107–126. https://doi.org/10.1016/j.jclepro.2017.09.248

Plieninger, T. (2007) Compatibility of livestock grazing with stand regeneration in Mediterranean holm oak parklands. J Nat Conserv 15:1–9. doi: 10.1016/j.jnc.2005.09.002

Pulido, F.J.; Díaz,M. (2005) Regeneration of a Mediterranean oak: a whole-cycle approach. Ecoscience 12:92–102. doi:10.2980/i1195-6860-12-1-92.1

Sá-Sousa, P., 2014. The Portuguese montado: conciliating ecological values with human demands within a dynamic agroforestry system. Ann. For. Sci. 71, 1–3. https://doi.org/10.1007/s13595-013-0338-0.

Sales-Baptista, E.; Abreu M.C.; Ferraz-de-Oliveira, M.I. (2015) Overgrazing in the Montado? The need for monitoring grazing pressure at paddock scale. Agroforest Syst. doi:10.1007/s10457-014-9785-3

Salgueiro, J. (2005). Ervas, Usos e Saberes – Plantas Medicinais no Alentejo e outros Produtos Naturais. Edições Colibri/Marca – ADL

Sardão, R.; Alexandre, E.M.; Amaral, R.; Saraiva, J.; Pintado, M. (2019) Effect of high pressure processing on a functional acorn beverage. Abstract of XXVI Encontro Nacional da Sociedade Portuguesa de Química. Faculdade de Ciências da Universidade do Porto.

Schmidt, L.; Truninger, M.; Guerra, J.; Prista, P. (2016) Primeiro Grande Inquérito sobre Sustentabilidade - Relatório Final. Observatório do Ambiente e Sociedade.

Silva, J. S. (2007). Parte II A azinheira, ícone da paisagem alentejana, Introdução. In Os montados: muito para além das árvores. Volume 3 de Árvores e florestas de Portugal. Editora Fundação Luso-Americana (pp. 117)

Silva, S.; Costa, E.M.; Borges, A.; Carvalho, A.P.; Monteiro, M.J.; Pintado, M.M. (2016) Nutritional characterization of acorn flour (a traditional component of the Mediterranean gastronomical folklore)

Zack Sultan Blog (2013) Retro-Innovation: Is Nostalgia The Next Big Thing? (on-line). The Business Romantic. http://timleberecht.tumblr.com/post/47713794379/retroinnovation-is-nostalgia-the-next-big-thing Accessed 16.09.2013

Surová, D.; Pinto-Correia, T.; Marusak, R. (2014) Visual complexity and the montado do matter: landscape pattern preferences of user groups in Alentejo, Portugal. Ann For Sci 71:15–24. doi:10.1007/s13595-013-0330-8

Surová, D.; Ravera, F.; Guiomar, N.; Sastre, R.M.; Pinto-Correia, T. (2018) Contributions of Iberian silvo-pastoral landscapes to the well-being of contemporary society. Rangel. Ecol. Manag. 71, 560–570. https://doi.org/10.1016/j.rama.2017.12.005.

Tiberi, R.; Branco, M.; Bracalini, M.; Croci, F.; Panzavolta, T. (2016) Cork oak pests: a review of insect damage and management. Ann. For. Sci. 73 (2), 219–232. https://doi.org/10.1007/s13595-015-0534-1.

Tobler, C.; Visschers, V.H.; Siegrist, M. (2011) Eating green. Consumers' willingness to adopt ecological food consumption behaviors. Appetite 57(3):674-682. DOI: 10.1016/j.appet.2011.08.010

Winner, L. 1977. Autonomous Technology: Technics-out-of-Control as a Theme in Political Thought. Cambridge, Mass.: M.I.T. Press.

Warrington, T. (2008) What Consumers Really Want: Authenticity, Journal of Consumer Marketing, Vol. 25 No. 4, pp. 262-263. https://doi.org/10.1108/07363760810882461

DECOLONIZING NATURE? DOMINANT WORLDVIEWS AND WORLDVIEWS OF AGROECOLOGICAL FARMERS IN GERMANY TO ADDRESS THE GLOBAL ENVIRONMENTAL CRISIS

Stephanie Domptail, Jennifer Hirsch, Ernst-August Nuppenau

Institute for agricultural policy and market research, University of Giessen, Germany.

Abstract

In Western Europe, farmers are embedded in a secular culture. This culture, characterized by a worldview where man and nature are separated and opposed, individualism is highly valued, capitalism rules exchanges and where the end production of food, rather than the process of food production, is central to food systems.

Agroecological approaches aim for farmers to entertain fundamentally different relationships between agriculture and the natural/social environment. Such a reconnection with the environment requires that farmers act based on an alternative worldview. Agroecological movements claim that their practices are based on a holistic worldview of nature. Yet, we currently have little cultural information about agroecological farmers in Western Europe.

The contribution thus explores the worldview of agroecological farmers in Germany in order to identify how they conceptualize their connection with nature and whether new connections to people are implied as well. More specifically, we attempt to answer the two questions: (1) How does the worldview of agroecological farmers in Germany make use of a decolonized perspective in order to reconstruct their relations to nature? And (2) Which place do farmers perceive for themselves in their environment with regard to important societal challenges such as climate change?

The paper first analyses the fundament of the Western worldview and ontological principles of alternative worldviews. The Human-Nature connections are interpreted making use of the Gaia theory and the integrative worldview. It then presents a reconstructive analysis of narratives collected from agroecological farmers of one farmer union via in-depth interviews. Results show that both colonized and decolonized perspectives of nature co-exist and that farmers perceive their activity as a responsibility towards the environment and society at the local, landscape and even global scale.

Investigating the ontological basis for the practice of agroecology in the Western European context can reveal fundaments to foster the agroecological transition and insights to the role agroecological farmers want to play in the wider food system.

Introduction

According to the Millennium Ecosystem Assessment, agriculture contributes more to the destabilization of ecosystem functions than any other single human activity (MA, 2005). Agriculture, forestry and other land-use activities accounted for 23% of the total net anthropogenic emissions of greenhouse gas (IPCC Report, 2019). The use of the Earth through hunting, foraging, land clearing and agriculture has always had some transformative effects on nature (Ellis et al., 2013). However, modern industrial agriculture has intensified and enlarged these effects spawning a global environmental crisis (Callicott, 1990). Litfin (2003) and Levins (2006) refer to a megacrisis “expressed in increasing demand on depleting resources, pollution, new and resurgent diseases, climate change, growing inequality, increased vulnerability to disasters of all kinds, loss of biodiversity, the erosion of productive systems, and recurrent conflict within our species.” (Levins 2006:35).

At the same time, no other human activity is as basic and central as food production for human sustenance. Thus, agriculture implies both Man’s use of nature and our dependency on it (Sanford, 2011). Agriculture represents the cornerstone of Human-Nature interaction where both humans’ and Earth’s needs may be reunited. Thereby, it has the potential to contribute greatly to solving the global environmental crises. The magnitude of the challenge may arise from its root in our culture's philosophy, as suggested by environmental sociologists.

Capra (1984) also understands the numerous environmental problems as the expression of a single crisis of perception. It "derives from the fact that we are trying to apply concepts of an outdated worldview – the mechanistic worldview of Cartesian-Newtonian science – to a reality that can no longer be understood in terms of these concepts." (Capra, 1984: 15-16). Levins (2006) points to a crisis of relationship, rooted in "a pervasive and intensifying dysfunctional relationship between our species and the rest of nature".

Agriculture, as all human activities, is the expression of human culture. According to Callicott (1988:3) a culture's agriculture reveals its "fundamental metaphysical beliefs and values. The beliefs characterizing Western Culture are "the emblematic faith in technology, the doctrine of progress, the centrality of instrumental reason, the sanctity of individual freedom, the denial of the sacred", according to Litfin (2003: 30). She identifies these beliefs as "sources of an environmentally destructive cultural tendency". These beliefs and alleged causes of our complex crisis are rooted in the same 'philosophy', which is known as the Western/secular/mechanistic worldview or the Cartesian paradigm. Kirschenmann (2005) argues that worldviews – and today the Western worldview - shape both our perceptions and actions. Thus, worldviews are fundamental in the transformation towards a sustainable agricultural and food system.

In the science arena, environmental sociology attempts to define the fundaments of an "integrative" or ecological worldview that could reunite Earth and human needs and lead to a more sustainable Human-Nature relationship. The proposed worldview is rooted in systems' theory and stresses the co-evolutionary relationship between mind and action, between worldviews and the way society constructs its relationship to nature and its own structures. In parallel, agroecology proposes as a set of alternative farming principles (Nichols et al., 2017), and is presented as a paradigm for an alternative food system (Gliessman, 2016; Oehen et al., 2015) in an attempt to resolve environmental and social problems. Its transformative potential (Giraldo and Rosset, 2016; De Schutter, 2011) rests, according to De Schutter (2017), on the fact that agroecology is based on an alternative, radically different Human-Nature relationship, that is, a new worldview. This paper seeks to bring together these theoretical and practical attempts to construct a worldview that sustains a new and sustainable relationship between Man and Nature.

What would be key concepts in a new worldview transcending the Human-Nature divide and inspiring a more sustainable agriculture? In comparison, how does the worldview of agroecological farmers in Germany make use of a decolonized perspective in order to reconstruct their relations to nature? Which place do farmers perceive for themselves in their environment with regard to important societal challenges such as climate change?

The paper first retraces the roots of the worldview that industrial agriculture is based on, and introduces an alternative integral worldview. Since stories people tell and rely on to see the world and stories' metaphoric and narrative realms are the expression of worldviews (Litfin, 2003), this paper presents in a second step a reconstructive qualitative analysis of the worldview of agroecological farmers in Germany and of their perceived role in the global environmental crisis.

Investigating the ontological basis for the practice of agroecology in the Western European context can reveal fundaments to foster the agroecological transition and also insights into the role agroecological farmers want to play in the wider food/environmental system. Indeed, a new metaphor can further help to set in motion a cognitive transformation at the level of a whole society by raising awareness of the faulty system and by calling the old model(s) into question (Hirsch & Norton, 2012).

Background: the emergence and establishment of the Western worldview in agriculture

The emergence of a mechanistic worldview of nature

Capra (1984) describes the dominant worldview in Europe in pre-modern times prior to 1500 as organic. Science generally pursued the development of a profound understanding of nature in order to live in harmony with it. In contrast, contemporary science seeks to predict and control. At the root of contemporary science is the scientific revolution, which relies on three major premises.

First, the scientific revolution separated objects from subjects. Natural sciences became exclusively occupied with material objects (matter) and their quantifiable and measurable properties. They excluded other properties, such as color, sound, smell and taste, and in general life and spirituality (mind) (Capra, 1984). The belief that certainty in knowledge can be achieved only via the separation of mind and matter became central to the Western worldview and science.

Second, a great contribution to science was the analytical scientific method developed by Descartes (in the 17th century). Nature was portrayed as a machine, as "working according to mechanical laws, and everything in the material world could be explained in terms of the arrangement and movement of its parts." (Capra, 1984:60). Animals were production automata. However, this analytical method has resulted in a fragmented vision of the world, coined as reductionist. The term reductionist refers to "the belief that all aspects of complex phenomena can be understood by reducing them to their constituent parts" and ignoring the role of relationships between parts" (Ibid.).

Finally, another important turning point in the representations of humans and nature was the incorporation in the Western worldview of Bacon's idea that "knowledge is power" and that man, through science, could control nature. This contributed to the further transformation of the ancient concept of a nurturing Mother Earth into the patriarchal metaphor of the world as a machine (Capra, 1984).

A primary consequence of the Cartesian division between spirit and matter was that achieving an objective description of nature became the ideal of all science (Muraca, 2016). Second, the goal of science became the generation of knowledge that would enable the human species to dominate and control nature and to invent technologies that could modify the world (Capra, 1984:55-56; Kirschenmann, 2005).

This mechanical view on nature turned into the dominant scientific paradigm for the next three centuries and shaped our modern agriculture (Callicot, 1990). Applied to sociology, it led to the idea that human minds, as powerful mechanisms, could adapt quickly to any ecological change. Catton and Dunlap (1978) termed this powerful paradigm which underlies agrarian modernization theories in the second half of the 20th century the 'Human Exemptionalism Paradigm'. The scientific paradigm was broadened to a general Western worldview, which is summarized by Capra (1984:31) in these terms:

Belief in the scientific method as the only valid approach to knowledge; the view of the universe as a mechanical system composed of elementary material building blocks; the view of life in society as a competitive struggle for existence; and the belief in unlimited material progress to be achieved through economic and technological growth.

Western Worldview and agriculture

Callicott (1988; 1990) summarizes how the mechanistic worldview conceptualizes modern agriculture as follows: The soil is perceived as a mere physical substrate, providing space and mechanical support for plants. Plants are complex assemblages of simple elements. The (potentially engineered) DNA of plant cells produces carbohydrates, fed as energy to agroanimals, and ultimately humans. As on an assembly line, processes are broken down to the smallest steps. The "[p]roducts are standardized; scale is magnified; and crops are specialized and monocultured." (Callicott, 1988:5). Importantly, agricultural goals, such as increases in yield, pest control, soil fertility, etc... were believed to be achievable "Cartesian-style, by finding a separate solution for each and summing the results" (Callicott, 1990:41).

The modernization of farming systems involved a series of transitions: from labor-intensive to capital-intensive; from heterogeneous to homogeneous; from small scale to large-scale; from subjection to nature to domination of nature; from superstition to science; and from the production of food to the production of commodities (Levins, 2006:38). A central example of the application of the Cartesian scientific approach to farming is the work of Justus von Liebig in the 19th century. After his identification of the role nitrogen, potassium and phosphorus play in feeding plants, von Liebig argued that the labor intensive nutrient cycling practices could be replaced with the application of chemical fertilizers. He inspired farmers to abandon their mixed farming practices to turn towards the specialized production of a few high-value crops (Kirschenmann, 2005).

The dominant narratives of conquering nature and manipulating parts of a machine– which emanated from the Scientific Revolution and underlie Western agricultural practices- are (still) presented as natural and inevitable within both the scientific and the 'feed the world' discourse (Litfin, 2003:29; Sanford, 2011:289). Yet today, modern agriculture is denunciated as a form of colonialism of nature. Guzmán & Woodgate (2015) also claim that ways of farming that did not follow rules of modernity were impoverished.

The problem is that the mechanistic worldview, with its machine metaphor and the fragmentation doctrine, is too narrow. The challenge ahead of us is to abandon the dichotomies through which we see the world today, such as the Man-Nature divide, the material and spiritual divide, etc... Science, as well as groups and networks from the practice in the field, are seeking new principles and paradigms for their organization (Capra, 1984).

An integrative worldview: theoretical developments and practice in agroecology

Currents of environmentalism have developed as a response to the ecological degradation ensuing from modern instrumental usage of nature. The first current refers to exclusive conservation projects such as nature parks where Nature is seen as wild, primitive, naïve and needing (richer) human protection (from other humans). The second current refers to precision agriculture, climate-smart agriculture, nutrition agriculture and the like (Oehen et al., 2015); practices which aim at using resources more efficiently to garanty their long term contribution. These hegemonic currents of environmentalism perpetuate the dichotomy between man and nature and the objectifying and instrumentalizing view on nature rooted in modern science (Muraca, 2016.). Yet, they do not represent a paradigm shift, in which thoughts, perceptions and values would shift fundamentally (Capra, 1984).

Towards an integrative worldview – theoretical perspective

The core principles of a new paradigm shall attempt to reformulate the crucial (ethical and cognitive) questions of who we are in relationship to the environment and of how can we meet both Human and Earth needs.

A third current of environmentalism, termed environmentalism of the poor by Guha and Martinez-Alier (1997) refers to the struggles of small farmers, women and indigenous people to preserve their collective livelihoods as well as their vision of a self-determined and sustainable life in their community. Their language and narratives express

a radically different [from the Western paradigm] understanding of the relation to the 'territory,' with all its inhabitants included in what can best be called a cosmo-anthropo-vision, in which interconnection among different levels of the real (biophysical, human, supernatural) leads to specific society-nature relations and nature-culture regimes. (Muraca, 2016:35)

Escobar (2008:154) considers this a decolonial view on nature that "calls for seeing the interrelatedness of ecological, economic, and cultural processes that come to produce what humans call nature" (quoted in Muraca, 2016: 35). Two theoretical concepts help qualify the beliefs and worldview the Environmentalism of the poor is based on. These are the integral perspective (Litfin, 2003) and radical relationism (Muraca, 2016).

First, the integral perspective, developed by Karen Litfin (2003) is built on "the premise that consciousness is ontologically prior to action" (p. 29). Thus, the global problem of our relation to nature is rooted in a dysfunctional mode of consciousness. A next stage of human consciousness shall bring the understanding that humanity and nature, spirit and matter, are two dimensions of a single reality (Litfin, 2003). It foresees a unique responsability (rather than privilege) to humans to develop their consciousness and find new modes of ontologically closing the gap between mind and matter (ibid.).

Second, radical relationism argues that "relations are ontologically prior to and constitutive of entities, rather than being conceived as external link(ing) between them" (Muraca, 2016: 19). Thus, experience is created through "a web of constitutive relations that include the emotional disposition of the act of grasping itself" (Muraca, 2016: 20). Object and subject interact and co-create one another. By contrast, the Western worldview depicts objects as pre-existing substrate and fails to acknowledge these relationships. One consequence of radical relationism is the necessity to consider farming systems holistically as constituted of parts which acquire meaning through their relationships with other parts. For instance, soil fertility is the corner stone of healthy farming systems rather than the optimal concentrations of N, P and K.

New mental models to link global to local

Concomitantly to alternative ontologies, Hirsch & Norton (2012) propose that global issues such as climate change can best be addressed by defining a new metaphor of the world. This metaphor plays the role of a mental model. Our inner mental models mirror the outer reality. By changing our metaphors and values, we change our actions., A new metaphor can incite an individual as well as a society to act upon the outer world and shape the environment quite effectively (Capra, 1984). In the case of climate change, it should allow us to "think globally, act locally".

An interesting mental model for the farming issue according to Litfin (2011) is thus the "Gaia theory, an interdisciplinary scientific perspective that understands Earth holistically as an integrated, self-regulating biogeochemical system". As an archetypal, Gaia theory is consistent with and can be seen as an application of the concepts of integral worldview and radical relationism, outlined above.

Three qualities of living systems, i.e. holism, autopoiesis and symbiotic networks can help steer human systems toward sustainability (Litfin, 2011: 421). Holism is expressed in Gaia theory by the representation that Gaia (the Earth) as "the largest known instance of a living system, which in turn entails countless subsets in the form of nested living systems of biota and their environments" (Litfin, 2011: 421). Thus, system thinking opposes the thinking of production as a linear process from resource to waste. Second, autopoietic refers to the capacity of maintaining the system and its function in time. Thus, the purpose of the system, that is, the functions that should pertain, is a fundamental philosophical question. Currently, growth constitutes the accepted purpose of the global economy. Yet, its infinite desirability on a finite planet causes Gaian-scale perturbations. Rather, the integrity and the stability of the Gaian system should become the core human purpose (Litfin, 2011:421). The third quality of living systems, the symbiotic networks, refers to the idea that the world consists of relations among objects. It "stands in contrast to modern political and psychological notions of human independence" (ibid.). The Gaia theory relies on symbiotic relationships and cooperation for survival in contrast to the neo-Darwinist view of life based on competition.

These principles appear in other emerging worldviews such as the *ecological worldview* which corresponds to the vision for a scientifically informed ecological agriculture (Callicott, 1990:45-46).

Agroecology as the enactment of the Gaia theory?

For agriculture and the food system, the mission is to transform the food system “into a viable subset of Gaia, which means approaching it as a holistic and autopoietic living system organized as a network of relations” nourishing people and ecosystems (Litfin, 2011: 427).

Callicott (1988:3) argues that “agroecology translate[s] this abstract new vision into a concrete agricultural vocabulary: The farmstead is regarded as an artificial ecosystem with a multiplicity of diverse plant and animal constituents interacting with one another and with environing natural ecosystems in complex and mutually supporting ways”. The idea that “agro-ecosystems should mimic the biodiversity levels and functioning of natural ecosystems” lies at the heart of agro-ecology while “[s]uch agricultural mimics, like their natural models, can be productive, pest resistant and nutrient conserving” (Pimbert, 2015: 287). Principles for agroecology in the field (Nicholls et al., 2017) and in the food system (Gliessman 2016) express a systemic view of natural processes and agricultural practices.

In addition and fundamental to the agroecological approach is the understanding of nature as active participant in processes of production and change (Guzmán & Woodgate, 2015), which reminds of the co-creation of subject-object mentioned earlier. Further, the material and energetic sustainability – besides the economic efficiency- of agricultural systems emerges as a goal of agroecology (Guzmán & Woodgate, 2015).

Thus, for Callicott (1988:8), agroecology expresses a new paradigm for agriculture. Litfin (2011) does suggest that organic and agroecological farmers have adopted “a Gaian understanding of soil as a living web of symbiotic networks rather than an inert receptacle for chemical inputs”. Rosset and Martinez-Torres (2013) suggest that this view of nature is held by the members of the agroecological movement in South America. Yet, we are not aware of any studies exploring western farmers’ worldviews and confirming this theory.

Methods and case study

The role of agricultural narratives and metaphors

We start from the idea that language is constitutive of reality, rather than simply describing it (Escobar, 1996 as quoted in Guzmán & Woodgate, 2015: 13). This means that language such as metaphors and narratives structures agricultural paradigms and practices. Indeed, different metaphoric realms characterize industrial agriculture, indigenous and alternative agricultures or conservation.

Narrative and metaphor have much to do with ethics. Narratives help us develop and enact our ethical frameworks and think through various courses of action, depicting the consequences of our choices. Narratives are also morally binding (Sanford, 2011). In agroecology, we expect narratives to be rooted in the Gaia or ecological worldview. They may imagine agricultural practices that consider effects on multiple human and non-human communities (Sanford 2011: 284) and reunify their needs.

Case study and data collection

We chose to analyse narratives of agroecological farmers in Germany. The country has undergone a large-scale structural change in the last decades pressing conventional farmers to give up their farming or to get bigger (Domptail et al., 2018). At the same time, the share of organic farmers in Germany is lower than in its neighbors France and Austria. Yet, Germany seeks to be a leader in the climate change mitigation.

The case analysed is that of a small peasant farmers' association in Western Germany in a region domianted by large scale arable farming but adjacent to more hilly grassland landscapes. The association stands up for a socially equitable and environmentally sustainable agriculture and the establishment of conducive conditions. Its members include both conventional and organic farmers, with medium and small-sized farms. Anyone interested in supporting the aim of maintaining peasant farming, shepperds, horticulture and improve their lot may join. The association conducts political and agronomic events and supports the cooperation between farms and groups of citizens. It is also a cofounder of the European Coordination Via Campesina, an umbrella organization of peasant farmers taking part in an international fight for food sovereignty.

We follow a purposeful sampling strategy targeting both women and men farmers, conventional and organic farmers, as well as farmers with different farming systems such as arable, mixed, dairy system or horticulture. The sample and data consist of six in-depth interviews. The face to face interviews were conducted at the farmers' homsteads between october 2020 and January 2020. Farmers were first asked to narrate their farming life trajectories. Some of the topics mentioned were then depended using questions developed to address the heuristics detailed below. Additional facts about the farms and farming systems were collected additionally, when not mentioned before.

Only two farms, both organic, are analysed in the present version of this paper. Farm B is a mixte farm while Farm A is a grassland based cattle rearing farm with own slaughterhouse of 350 ha. Farm B is a mixte farm arable-cattle with 90 ha including 50 of arable cultivation. Both deploy considerable efforts to integrate biodiversity-foresting and animal-friendly practices in their farming system (see details in annex 1).

Qualitative reconstructive analysis

Reconstructive research seeks to investigate how humans mentally and thus practically shape the world they live in. Reconstruction means that we examine how social meaning is constructed by the application of linguistic means (signs and symbols) and how such social meaning is expressed in a documentary manner (cf. Kruse, 2014: 472). We apply an integrative basis procedure (*Integratives Basisverfahren*) by Kruse (2014), which aims to let the "data talk" in an inductive manner. Yet, due to the impracticality of a solely inductive analysis, the integrative procedure recommends the use of the heuristics of research objects (*forschungsgegenständliche Analyseheuristiken*) to structure and systemize the analysis openly. These heuristics can be understood as sensitizing concepts (cf. Blumer, 1954) which function as 'scanners' or interpretation guides for detecting the respective structures of meaning within the text.

We explore farmers' concepts of nature and the concomitant self-world relations by investigating five domains: (1) their understanding of nature and Man-Nature relations; (2) the profession of farming and its objectivity; (3) the nature of their knowledge; (4) human responsibility towards the global crisis and climate change; and (5) their relation to the political and food systems. Table 1 shows the research object-specific heuristics formulated for each domain.

<u>Table 1:</u> *Research object-specific heuristics used as scanners in the text analysis.*

Understanding of nature and human-nature (power) relations	How is nature described? (non-Western concepts of nature, e.g. Mother Earth, a home and living being or rather a source of resources?)
	How does the interviewed person position him/herself in relation to nature?

	How does the interviewed person perceive he/she reunifies her needs and the needs of nature through their activity? Is there a creative interaction between human activities and nature's productivity?
Work conception, professional identity and spirituality	Does the interviewed person mention spiritual aspects? What is the role of personal relationships to things in the farming system, that is, the significance of emotion, instinct and intuition in the farming activities?
	How does the interviewed person describe his/her professional identity in relation to other farming approaches?
	Is it rather about competition or cooperation? (De)growth?
Knowledge and system thinking	How does the interviewed person deal with the complexity of the natural system he/she interacts with? How does he/she perceive the role of scientific knowledge and technology? How does he/she deal with uncertainty?
	What is the aim of farm management (integrity and stability - or what other concepts are guiding principles)? Does the interviewed person make use of linear thinking or do they think in circles?
Responsibility	What is the perception of the interviewed person of his/her responsibility? At which scale (farm or world)? Do they hint at a "system" identity, such as planetary citizen or earth steward?
	How does the interviewed person perceive his/her (socio-ecological) agency with regard to the global environmental crises and especially climate change?
	How does the interviewed person describe his/her role in socio-political change? On what scale?
Embeddedness/connectedness vs individuality, and autonomy	How does the interviewed person position him/herself in the community? In society? in the world?
	How does the person relate to the higher systems it is embedded in, especially the political and food systems? Does the person strive for autonomy?
	Is the person's agenda at the farm or local scale? or is it connected with other people's agendas and aimed at enacting change on a bigger scale?
	How is globalism perceived and what are the perceived relationships between the global and the particular, the whole and subsystems?

Preliminary results and discussion: Worldviews in an agroecological farmers' union in Germany

The narratives are analyzed individually first and then compared.

Farm A. The farm in the global world.

The first most stricking feature of farmer A's worldview is the co-existence of a sense of respectful submission towards nature, due to human dependency on nature and the constraints it imposes on production processes, together with a strong sense of actively shaping nature, in the form of nature-like (*Naturnahe*) production systems. Although the farmer perceives that he curves nature according his will, he believes that his practices are the only positive way do to it because they maintain the qualities of nature which together build the life basis: air, water, soils and biodiversity. To maintain this lifebasis ("*Lebensgrundlage*") **intakt** is the central aim of the farming activity (Verbatim 1 and 2; in original transcript and language in annex 2).

" but (.) I don't LET eh eh eh nature to GROW as it in an ideal case would like to (1) but (1) Yes our lifeBASIS is eh here the INTERFERENCE in Nature we have to hum say it this way". Farmer A, §54.

„we are the FIRst in [OUR REGION], who have started again to (.) THIS EXTENT to MOW with the DOUBLEblade mowing machine (.) that means that we acquired a=a machine a MOWING technique (.) which is insect-FRIEndly and hum !YES! it involved many Risks=and also !MUCH! TROUble and EFForts TIMEwise and Financial hum (.) eh where we eh STILL believe today that THIS is the RIGHT thing to do !TO! pra-pracTICE the most POSItive possible !FORM! of agriculture" (Farmer A. § X).

The second main feature is the understanding of the farm as one element of the global social and ecological system and dynamics. The interaction with nature is understood in the anthropocen context. Indeed, the farmer perceives the role of humans in shaping nature as immense and at the same time endosses, in that role, the responsibility of shaping farming so that it addresses the global crises of social inequality and climate change. Thereby, those farmings practices are perceived as a communication, a form of dialogue, between the farmer and nature, as well as between the farmer and the world. For instance, the farmer perceives perceives certain aims and related practices as a political act towards a fairer world (Verbatim 3).

"YES what we (.) in addITION try to do is to MANAGE the PAStures (1) so that eh (.) okay this is now also political- BUT it just came to my mind YA eh that we try to build build UP our HUMUS that means to BIND CARBON Dioxyde from the air" (farmer A, §28).

Local marketing is also perceived as a way to avoid unfair competition with the global south (Verbatim 4).

[Industrial agricutlure] "attempts with SMALLEST POSSIble WORK use to produce the highest OUTput (.) THIS resULTS of course from the DISCREPANCY (.) between SIGNIFICATION [orig. WERTigkeit] of the FOOD and our general wage level (.) but it also induces that we (.) eh=eh OTHER foods (.) primarily things that are=are=are WORKintensive in their production (.) WE HAUL them from Other regions of the world" (Farmer A, §47).

Farm B. An island in the midst of desolation

The most stricking feature in Farmer B's worldview is the representation of nature as perfect. Nature is the embodiment of God, is surprising by its powers and wonders and is fundamentally associated with two key attributes of diversity and complixity. Through a "reverential" attitude and "fascination", the farmer takes nature as as inspiring role model, which she uses to create habitats or spaces for living ("*Lebensraum*") for humans and other species, today and tomorrow. She perceives her exchanges with nature as a "give-and-receive" relationship where she contributes to sustain or increase the lifebasis and gets in return a haverst and a meaningful job. She describes this as a tightrope walk (*Gratwanderung*), a challenge in order to maintain a certain balance (verbatim 5):

"So: it is of course eh also a TIGHTrope walk because eh ya OTHERS SAY (.) well then let the nature completely ALONE so (.) mhm to !GROW! as IT WISHES (.) mhm but I SEE this again NOT this way because when then a plot isn't used AT ALL, then eh it is not always BETTER so you find the highest humus CONTENT [orig. AUFBAU] under PASTURES grazed by CATTLE (.) and where many different GRASSES grow and FLOWERS and all those SPEICIES they are only there when someone makes HAY and also hm MOWS (.) cuts the grass and (.) takes it AWAY so eh (1) it (.) is always about needing to maintain the EQUILIbrium " (Farmer B §15).

Second the farmer understands the farm as an element of the living landscape, which acts as an organism (Verbatim 6).

"just HOW the landscape ehm (1) just NOURISHES itself from the construction of PONDS and irrigation systems that are integrated in the landscape (.) mhm (1) that also EACH corner nearly EVERY plot has its VERY special PROPERties that one should eh SEE and use". Farmer B §9.

In describing the landscape as a place of desolation (large scale monocultures), she perceives her farming activity as a counter-action, and in fact a **nature protection** act. For instance, she uses flower strips and mowing techniques, which support insect and small fauna diversity and chooses her crop rotation according to surrounding cultures to ensure an ecological stability in the landscape (Verbatim 7):

"When you LOOK at the landscape, you see (.) in fact !DESOLATEDNESS! (.) so you see insanely large areas without diversity eh (.) cultivated with one crop only (.) no hedges (.) these are things (.) I try to somehow COUNTERACT (.) so I try most of the time to CULTIVATE MIXTURES of crops (.) FLOWERIng strips surround EACH of my FIELD!EDGES! (mhm) at the BORDER to the next FIELD (.) I try to cultivate crops that flower when NOTHING flowers in the landscape (.) ehm yes (.) I (.) actually do (.) quite some (.) nature PROTECTING (.) or nature conservation eh ya." Farmer A.

She perceives a responsibility to protect other species in this context and has an emtional bond with them.

Equal relationship with nature: good, fair and fear

The human-nature relationship described is one of respectiful partnering and egalitarianism.

A first common attitude towards nature is amazement. Nature, in its powers, its complexity - web of linkages and complementarity - its diversity, is perceived as marvelous and beautiful. The amazement suggests that farmers observe nature and its works (functioning) very closely – this observation of nature's work is one essence of a certain humility, or recogntion that nature has its own path and powers. The observation is also at the basis of the dialogue with nature.

In parallel, one important element of the nature-farmer relationship is a very developed understanding of the earth, landscape and farm as nested and complex systems. This is a key guideline for the farming practices and farm design. At the same time, the web of complexity is related to fears: because chains of causalites are complex, consequences can be numberous. Biodiverity loss, climate change and social unrest were feared consequences of the system behavior of Earth.

These two elements enable a third dimension of the nature-human relationship: the usage/crafting dimension. While farmers depend upon and admire nature, **they shape it** so as to create a life basis and life spaces supporting both humans and other species needs. Farmers feel particularly empowered to make the choice of "positive" practices that enable them to make the "good" decisions towards a nurturing land use. Importantly, they perceive the beauty of nature in complex and diverse **man-made** (agroecological) agricutural systems.

Local farming for global consequences

Perhaps the most striking sense of citizen responsibility taken up by the farmers is that they wish to preserve nature as a life-basis and a space for life for all species, for future generations and for all because they want to help save the world. They do so through great expenditure of time, effort and money.

The two interviewfurther address two scales of acting responsibly. First at the context of the landscape, the farmer strives to provide islands of biodiversity to sustainable life across the landscape. Second, at the scale of the earth, farmers feel that their actions are connected in a telecoupling manner with local happenings elsewhere (e.g. in the global south, in the atmosphere) and do act accordingly by designing farming systems able to address many short shortcoming of the dominant industrial agriculture model. This desire to address current global issues is further represented in the vocabulary used by Farmer A which he interstingly co-opts from the productionist paradigm and applies to agroecological practices (“highly productive”, “intensive production”, “rational thinking”).

The “Lebensraum”

The life-basis concept, framed in the interviews as soils, water, air and biodiversity and complexity, appears as a key concept to reconcile views of nature as wild versus tamed. This concept provides a new aim for the agricultural activity, based on the idea that agricutlure can be the crafting act of turning nature into a life-support system for multiple species. It transcends the western utilitarian view of nature as conserved or exploited to come close to the concept of environmentalism of the poor (Martinez-Alier, 1997), characterised by the perception of dependency on nature. This suggests that, perhaps, agroecological farmers are developing an environmentalism of the peasant, but a peasant of the global world, very far from the romanticized view that peasants are cutting themselves from the modern world and its challenges.

Conclusions

Alternative worldviews to the dominant Western worldview are essential to improving the food system and addressing climate change and other environmental crises because worldviews shape (agricultural) actions. Agroecology claims to be different from all forms of present modern agriculture systems and to have the potential to address the global environmental crisis and climate change because it is based on a different worldview; one that reflects a decolonized and systemic an-Nature relationship.

The current dominant Western worldview is based on a reductionist approach to nature and analysis, and on the idea that we can control nature. It has fostered an extractive form of modern agriculture which alienates humans, and farmer in particular, from an experiencial communication and interaction with nature. Integrative and ecological worldviews, as well as the Gaia theory are being developed by science in an attempt to reconcile humans’ and Earth’s needs. These address the human consciousness about their relationship to nature and they attempt to reunify mind and matter so as to depart from a mechanistic approach to natural resource management. Agroecological farmers claim to operate on such a decolonized relationship and a systemic understanding of nature. Our analysis of narratives from agroecological farmers in an arable fertile region of Germany shows that farmers have adopted Gaian worldviews seing the farm as an element of the landscape organism and of the earth social and ecological organism. Under the new worldview, the farmer, his motivation and his operating territory matter. Production does not happen alone but rather in a territory and as the result of the interaction of actors among themselves and with their environment. This worldview enables farmers to indeed enact values which they share and that address their role with regard to the global environmental crisis.

References

Amann, K. & Hirschauer, S. (1997). Die Befremdung der eigenen Kultur. Ein Programm. In S. Hirschauer & K. Amann (eds.), *Die Befremdung der eigenen Kultur: zur ethnographischen Herausforderung soziologischer Empirie* (p. 7-52). Frankfurt/M: Suhrcamp.

Callicott, J.B. (1988). Agroecology in Context. *Journal of Agricultural Ethics, 1*, 3-9.

Callicott, J.B. (1990). The Metaphysical Transition in Farming: From the Newtonian-Mechanical to the Eltonian Ecological. *Journal of Agricultural Ethics, 3* (1), 36-49.

Capra, F. (1984). *The Turning Point. Science, Society, and the Rising Culture.* New York: Bantam Books.

Catton, W. & Dunlap, R. Environmental sociology (1978). A new paradigm. *The American Sociologist, 13*: 41–49.

De Schutter O. (2017). The political economy of food systems reform. European Review of Agricultural Economics 44 (4): 705–731. DOI: 10.1093/erae/jbx009.

De Schutter, O. (2011). The transformative potential of agroecology. In: Eric Holt-Giménez eds. Food Movements Unite! Strategies to transform our food systems. Oakland, California: Food First Books, S. 224–242.

Domptail, S., S. Rauer, B. Müller, D. Mühlleitner, and E.-A. Nuppenau. (2018). 'From land restructuration to land grabbing – the political context of agroecology', 13th European IFSA Symposium. Mediterranean Agronomic Institute of Chania, 1-5 July.

Giraldo, O. F., and P. M. Rosset. (2016). Agroecology as a territory in dispute. Between institutionality and social movements. The Journal of Peasant Studies 45 (3): 545–564. DOI: 10.1080/03066150.2017.1353496.

Gliessman, S. (2016). Transforming food systems with agroecology. Agroecology and Sustainable Food Systems 40 (3): 187–189. DOI: 10.1080/21683565.2015.1130765.

González de Molina, M. (2013). Agroecology and Politics. How To Get Sustainability? About the Necessity for a Political Agroecology. *Agroecology and Sustainable Food Systems, 37* (1), 45-59.

Guha, R. (2000). The Paradox of Global Environmentalism. *Current History, 99* (640): 367–370.

Guzmán, E. & Woodgate, G. (2015). Transformative Agroecology: Foundations in agri-cultural practice, agrarian social thought and sociological theory. In V.E Mendez, C. M. Bacon, R. Cohen & S. R. Gliessmann (eds.), *Agroecology: A Transdisciplinary, Participatory and Action-oriented Approach* (p.1-24). Boca Raton: CRC Press.

IPCC (2019) 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Subject to final copy-edit and layout prior to its final publication. https://www.ipcc.ch/site/assets/uploads/2019/06/19R_V0_01_Overview_advance.pdf

Jackson, Wes (1987). *Altars of Unhewn Stone: Science and the Earth.* San Francisco: North Point Press.

Kirschenmann, F. L. (2005). Spirituality in Agriculture. Leopold Center Conference Papers, 6. Available at http://lib.dr.iastate.edu/leopold_conf/6 [27.05.2019].

Kruse, J. (2015). *Qualitative Interviewforschung. Ein integrativer Ansatz.* Weinheim/Basel: Beltz Juventa.

Kuhn, T. (1962). *The Structure of Scientific Revolutions.* Chicago: University of Chicago Press.

Levins, R. (2006). A Whole-systems View of Agriculture, People, and the Rest of Nature. In A. Cohn, J. Cook, M. Fernandéz, R. Reider & C. Steward (eds.), Agroecology and the Struggle for Food Sovereignty in the Americas, (p. 34-49). Nottingham; UK: Russel Press.

Litfin, K. (2003). Towards an Integral Perspective on World Politics: Secularism, Sovereignty and the Challenge of Global Ecology. *Journal of International Studies, 32* (1), 29-56.

Litfin, K. (2010). The Sacred and the Profane in the Ecological Politics of Sacrifice. In M. Maniates & J.M. Meyer (eds.), *The Environmental Politics of Sacrifice* (p. 117-143). Cambridge, MA: MIT Press.

Litfin, K. (2011). Thinking like a planet: Gaian politics and the transformation of the world food system. *Handbook of Global Environmental Politics, Second Edition,* 419-429.

Muraca, B. (2016). Relational Values: A Whiteheadian Alternative for Environmental Philosophy and Global Environmental Justice. *Balkan Journal of Philosophy, 8* (1), 19-38.

Nicholls, C. I., M. A. Altieri, and L. Vazquez. (2017). Chapter 1: Agroecological Principles for the Conversion of Farming Systems. In: Alexander Wezel, eds. Agroecological Practices for Sustainable Agriculture: WORLD SCIENTIFIC (EUROPE): 1–18.

Oehen, B., A. Hilbeck, H. Herren, A. Mueller, R. Home, U. Hoffman, E. Nelson, L. Levidow, and M. Pimbert. (2015). Feeding the people: Agroecology for Nourishing the World and Transforming the Agri-Food System. Bonn: Hg. v. IFOAM EU Group. Available from: http://www.ifoam-eu.org/sites/default/files/ifoameu_policy_ffe_feedingthepeople.pdf.

Pimbert, M. (2015). Agroecology as an Alternative Vision to Conventional Development and Climate-smart Agriculture. *Development, 58* (2-3), 286-298.

Rosset, P. M., and M. E. Martínez-Torres. (2012). Rural Social Movements and Agroecology. Context, Theory, and Process. Ecology and Society 17 (3): 17. DOI: 10.5751/ES-05000-170317.

Annexes

Annex 1: Description of the Case Study Farms

(Only the two farms used in the results section till 13.02. 2020; will be updated to 6 or 7 farms in a complementary version of this paper).

Farm A	(anonymous)
Size (ha):	330 ha
Ownership status:	1/3 own land, 2/3 leased land; bought the land and the farm together with his wife 20 years ago
Labor force:	3 adults (himself, his wife, and a partner), his children
Crops:	Arable farming on 20 ha in cooperation with another farm
Pasture and grassland:	310 ha
Woodland	none
Unused area:	2-3 ha fallow land
Number and species of animals:	Cattle (250-300: 90 Suckler cows, 90 One-year-olds, 90 Two-year-olds)
Meat business:	yes
Certification:	Naturland
Unions/clubs/associations:	Two peasant farming and one nature conservation associations
Gender:	male
Age:	Between 40 and 50
Education:	graduate
Experience as farmer	40 years total, 20 years on own farm
Greatest motivation:	Family
Greatest challenge:	Family
Farmer A started without his own farm and built up the present farm from scratch together with his wife in Germany about 20 years ago. They built their own slaughterhouse in order to be able to accompany the animals to their death and reduce their stress. As part of an integrated pasture management, the cattle spend 10 months a year outdoors on the pasture to maintain medium-high grass in order to increase soil fertility and to ultimately store air CO2. The cattle is fed without external inputs. The farmer is further concerned about biodiversity loss and therefore acquired a cost- and maintenance-intensive yet insect-friendly double blade mower. The family bears all the work on the farm and shares the enthusiasm for an environmentally and socially compatible small-scale agriculture with local and direct marketing, an international perspective and political engagement.	

Farm B	L. G.
Size (ha):	90 ha
Ownership status:	15% own land, 85% leased land together with a partner farm
Labor force:	3
Crops:	50 ha. Wheat, rye, barley, millet, pea, bean, grain fennel, sugar beet, various intermediate crops, sunflower (next year), buckwheat. Products of market gardening/ Orchard meadow: Sweet cherries, apples (apple juice); nuts, mirabelles and others
Pasture and grassland:	40 ha
Woodland	none
Unused area:	None (even though flower strips and hedges officially count as fallow land, but farmer considers them as tillage and landscape elements)
Animals:	Suckler cow herd (red mountain cattle) and 3 horses
Meat business:	Yes, but extensive; cattle rather used as caretakers of the landscape and forage processors
Certification:	Demeter
Unions/clubs/associations:	Several associations but active in one peasant farming association.
Gender:	female
Age:	Between 30 and 40
Education:	graduate
Experience as farmer	10 years, 6 years with own farm
Greatest motivation:	Her children
Greatest challenge:	Short days and having the strength to do what you want to do
L. G. started organic farming six years ago together with her husband in Center-West Germany. She is interested in interdependencies both on a small and large scale and completed training in permaculture in Australia. Questioning common practice in agriculture, she incorporated a high number and diversity of landscape spatial and temporal elements such as hedges, flower strips and animal friendly mowing dates on the whole of her farm. She is the president of the peasant farmer association. This year, she plans to offer seasonal gardens to bring agricultural activities, knowledge about food and its production closer to the people and to offer place for community and social interaction.	

Annex 2: Verbatim original transcripts and language.

Verbatim 1: mhm] die=die aber (.) aber die=die=die naTUR (.) nicht so LÄSST wie se EIgentlich WACHSEN würde so gern ma des im idealfall gern tun wöllte (1) aber (1) JA unsere lebensGRUNDlage is äh sch- <<Telefon klingelt>> IS hier der EINGRIFF in die naTUR des muss mer [mhm] so sagen" (Transkript Farmer A - Final, Absatz 54)

Verbatim 2: „wir jetzt die ERsten in HEssen (.) die angefangen ham wieder mit (.) in DEM UMFANG mit nem DOPPELmessermähwerk zu MÄhen (.) das heißt wir ham uns ein=eine maschINe angeschafft=eine MÄHtechnik angeschafft (.) die inSEKtenschONend scho- äh MÄht (.) u:nd=ä:hm (.) !JA! was mit viel RIsiken verbunden WAR=auch mit !VIEL! (1) ÄRger und AUFwand ZEITlich und FInanziell [mhm] (.) äh: wo wa aber jetzt doch äh IMmernoch der überzeugung sind dass DAS (.) das RICHtige is (.) !UM! (2) eine möglichst POsitive !FORM! der landbewirtschaftung zu prak-praktiZIERN (.) (Transkript Farmer A – Final)

Verbatim 3: „JA was wir (.) darüber hinAUS versuchen ist des GRASland SO zu beWIRTSCHAFTEN (1) dass äh:m (.) nagut des hat jetzt mit politisch n- ABER des fällt mir grad so ein [JA] äh dass wir=dass wir versuchen HUMUS aufzuBAUEN das heißt auch KOHLENstoff aus der luft zu BINDEN (.)" (Transkript Farmer A - Final, Absatz 28).

Verbatim 4: Industrielle LW „versucht mit !MÖG!lichst WENig !ARBEITS!einsatz MÖGLichst hohen AUS-OUTput zu erzeugen (.) DAS resulTIERT natürlich aus der DISKREPANZ (.) zwischen der WERTigkeit von den LEBENSmitteln und unserm allgemeinen lohnnivEAU (.) führt aber auch DAzu dass wir (.) äh=äh ANDERE lebenmittel (.) vor allen dingen SOLche die=die=die ARBEITSintensiv erzeugt werden (.) UNS aus ANdern regionen der welt ähm (.) HIERHER holen." (Transkript Farmer A - Final, Absatz 42)

Verbatim 5: „also: [ja] es is natürlich äh=auch so ne GRADwanderung weil äh (.) ja ANDERE SAGEN (.) dann muss man die natur ja ganz in RUHE lassen ver-also (.) ne [mhm] für SICH !WACHSEN! LASSEN (.) [mhm] aber des SEH ich dann wiederum NICH so weil wenn man dann (.) ne fläche GAR nich mehr bewirtschaftet dann ähm (2) is das nich unbedingt viel BESSER also den höchsten humusAUFBAU hat man (.) unte:r WIESEN die mit RINDERN beweidet werden (.) [mhm] und wo ganz viele GRÄSER drauf wachsen und BLUMEN und die:se ganzen (.) ARTEN die gibts nur wenn jemand da HEU macht und des gras auch m=MÄHT (.) [mhm] schneidet (.) und wieder WEGfährt also=äh (1) des äh (.) is immer so des (1) GLEICHgewicht was eingehalten werden muss" (Transkript Farmer B, Absatz 15)

Verbatim 6: „DA gabs auch ähm (1) !EINIGE! schlüsselerLEBNISSE WIE einfach die land (.) SCHAFT sich auch ähm (1) ja NÄHRT einfach durch anlage von TEICHEN und bewässerungssystemen die man dann in der landschaft integriert (.) [mhm] (1) dass doch auch (.) JEDE ecke quasi JEDER=jede fläche seine GANZ spezielle EIGENschaft hat die es äh zu SEHEN und zu nutzen gilt" (Transkript Farmer B, Absatz 9)

Verbatim 7: „wenn man (.) in die LANDschaft SCHAUT (.) sieht man (.) eigentlich ne große (1) !ÖDNIS! (.) FAST (.) also man sieht wahnsinnich große flächen ohne vielFA:LT äh (.) einfach mit einer kultur bestande:n (.) kaum hecken (1) des sind so dinge (.) da versuch ich irgendwie GEgenzuSTEUERN [mhm] also ich ähm (.) versuch meistens pflanzen im geMENGE anzuBAUEN (.) BLÜHstreifen sind am JEDEM meiner FELD!RÄNDER! [mhm] zum- an der GRENZE zum nächsten ACKER (.) ich versuch kulturen anzuBAUEN die blühen wenn sonst !NICHTS! blüht in der landschaft (.) [mhm] (.) ähm (2) ja (.) ich (.) mach schon (.) en zimmich ähm (1) naturSCHÜTZENDE (.) ode:r naturschutz äh=ja: (.) wie sagt man denn (.)" (Transkript Farmer B, Absatz 11)

CONCEPTION OF LOCAL CARBON MARKETS CONNECTING FARMERS AND COMPANIES: SOCIO-ECONOMIC OUTLINES OF INNOVATIVE SCHEMES

Thareau, B.[a], Seyni, N.[b], Coisnon, T.[c], Dupraz, P.[d]

[a] ESA, UP LARESS
[b] INRA, UMR SMART-LERECO
[c] Agrocampus Ouest, UMR SMART-LERECO
[d] INRA, UMR SMART-LERECO

Introduction

Various environmental policies promote the implementation and maintenance of hedgerows such as those within the framework of the agri-environmental contractualisation of the common agricultural policy (CAP), or planting support programmes run by local authorities. In context of the rise of "market-based policies", voluntary carbon markets appear as a possible way of valuing environmental carbon storage services. However, agriculture makes a modest contribution to compensation projects: 22% of the respondents surveyed by Tronquet (2017) say they compensate through agricultural projects, while 38% of the respondents would like to do so.

In the West of France, one of the important levers of carbon storage is the maintenance of hedgerows. Indeed, the French environmental public agency (ADEME) has identified hedgerows as one of the various ways to mitigate greenhouse gas emissions, particularly through carbon sequestration, in addition to other ecosystem services, including preventing erosion, the regulation of water flows and the improvement of biodiversity and landscape quality. This importance is endorced in the greater western region of France, particularly in the Pays de la Loire and Brittany areas where hedgerow conservation is paramount (ADEME, 2015). These claims in regard to the importance of hedgerows for carbon sequestration are also supported by research conducted on hedgerows, which has shown that the carbon stocks in soils observed in the vicinity of a hedgerow are higher than those observed in cultivated plots (Follain et al., 2007; Lacoste et al., 2015). Three reasons were given: (1) carbon inputs from the hedgerow's perennial vegetation are greater than those for annual crops, whose biomass is often partly exported; (2) deep mineral soil horizons below the hedgerow have a significant organic matter content relating to significant biological activity in the entire root depth of trees; (3) in situations subject to erosion, hedgerows can limit soil and carbon loss associated with eroded particles. Recent research measured the storage potential of hedgerows in the West of France (Pays de la Loire and Brittany). The research confirmed the estimations previously proposed by Pellerin et al. (2013) of approximately 0,5 $TeqCO^2$/100m/year for mixed hedgerows (in aerial, roots and soil compartments). This level of storage varies greatly in relation to the plant species composition of hedgerows, the age of hedgerows and the level of initial carbon stock in the soil (Viaud and Gautier, 2019). However, despite previous public and local policies intended for the maintenance of hedgerows, hedgerow length is still decreasing. The challenge of this study is therefore to find new ways to promote the maintenance and creation of hedgerows by farmers. Our project, therefore, examines the conditions for the development of volontary local carbon markets as a new way to enhance hedgerow maintenance and to mitigate climate change.

Carbon markets: singular schemes in agroecological transitio

Our project thus begins with an ambition to introduce new ways of enhancing hedgerow management in rural territories of Western France. But this ambition is far from new. As McCollin (2000) states, concern regarding hedgerow maintainance arose in the early part of twentiest century: following the American dustbowl episode, the focus of early conservation measures was often on the soil (and the microclimate effect of hedgerows as shelterbelts). Biodiversity started to become a key issue supported by conservationists in the 1970s. Meanwhile, a variety of arguments were discussed such as the visual benefits of hedgerows, and more recently the agronomic, zootechnic and economic benefits regarding grass and crop production or animal welfare. The role of hedgerows in carbon sequestration is of recent interest. If the concern for climate change mitigation emerged at the end of the last century, the identification of the maintainance of hedgerows as a key landscape component in climate change mitigation only emerged recently: in France, the publication of an INRA study in 2013 on the effect of agricultural practices on climate change mitigation has been a starting point. The authors estimate that the development of hedgerows on agricultural land could allow for 1.2 MTeqCO2 to be stored by 2030 in France, placing this measure at 10th rank of the 26 measures studied (Pellerin and Bamière, 2013).

At the same time, public schemes concerning the hedgerow management issue have evolved. Until the 1990s, in France as in other European countries, the state assigns rural management strategies to landowners and farmers (McCollin, 2000; Thareau and Billaud, 2014). In the 1990s, European legislation invested environmental issues, demonstrated by the establishment of the first agri-environmental measures. In France, the 2000s were a period of reinforcement of the role played by local communities in the animation of territorialized environmental projects (Thareau and Fabry, 2013). It was at this time that the first territorial climate projects emerged (2004). In 2009, the French State created a pivotal role for large local authorities with regard to local environmental policies: it extended their area of competency into the field of climate and biodiversity (Bertrand, 2013). However, local authorities have not yet integrated carbon offsetting into their policies to fight climate change (ADEME 2016).

In this context, carbon markets may be a unique mechanism for agriculture, particularly because they are a market-based instrument which could instigate private corporate investment, particularly in a political landscape dominated by a contractual logic between the French State or Europe and farmers (for example, AEMC for maintaining the hedgerows), public investment (such as, planting subsidies from local communities), or coercitive policies to protect hedgerows (for example, urban planning).

Research suggests that environmental innovations in the agricultural sector have been embraced, mainly as a result of CAP (AEM) Agri-Environmental Measures and subsidization. Research demonstrates that farmers' willingness to participate in agri-environmental schemes varies according to factors such as the duration of the contract, time spent on non-operational aspects, the level of payment, technical assistance, flexibility in relation to the requirements of the scheme and flexibility with regard to the area included in the project (Ruto et Garrod, 2009; Espinosa-Goded et al., 2010; Christensen et al., 2011; Siebert et al., 2006). The involvement of companies in an environmental scheme, have been studied in relation to corporate social responsibility (CSR) measures. Organizational factors influence a company’s commitment decision: size of the company, age, sector of activity and degree of innovation. Individual issues (gender, age, sensitivity and emotional commitment of the manager) are also deciding factors when it comes to adhering to a CSR policy (Cabagnols et Le Bas 2006; Labelle et St-pierre 2010; Spence et al 2007; Gherib, 2006). Some authors interpret a company’s commitment to sustainable development or CSR schemes as an attempt to enhance their image and gain a more competitive advantage (Cabagnols, 2006). Others seem to act for ethical reasons, environmental image or to anticipate future regulations (Chenost et al, 2010).

Some research explores more innovative schemes and questions the effects of these schemes on stakeholder involvement. Various forms of payment for ecosystem services are explored. They demonstrate that the conditions of some schemes do influence stakeholder involvement: the strong involvement of an intermediary and trusting relations within the farming community (Mariola, 2012). Schirpke et al. (2017) show that to succeed, these schemes should benefit from public support, and involve human resources to conduct a participatory process. This process should be inclusive for all types of stakeholders, to understand and consider stakeholders' values and objectives, to identify local dynamics, and to eventually, produce trust. Lockie (2013) underlines that the success of schemes such as cap and trade regimes in GHG emissions depends on the legitimacy of the scheme : the sucess relies on a clear understanding of the ecosystem services in question as well as a transparent, robust and broadly accepted institutional and regulatory framework for monitoring and trading.

This review underlines the role of contract or scheme characteristics in the involvement of stakeholders. Our project focuses on a proposition of volontary carbon markets. Such carbon markets relating to agriculture are not yet established in France, and therefore, the commitment from companies, farmers and local authorities remains uncertain. Our research aims to specify the outlines of such schemes to favour stakeholders involvement.

Method

Our research focused on three categories of stakeholders - farmers, companies and local authorities - regarding the objective and conditions of participation in a carbon market. For this, we conducted in 2018 and 2019 a survey of 88 respondents in 3 territories of Western France (22 companies and 45 farmers and 21 local authorities) to measure and explain their preferences. The results of this survey were consolidated into 3 focus groups comprising businesses, local representatives and farmers.

Measuring relative preferences for an innovative scheme

To enable respondents whose understanding of the carbon sequestration potential of hedgerows is minimal, to invest into little-known carbon market schemes, we chose : i) to provide information on the carbon sequestration potential of hedgerows and carbon market schemes before and during the interview; and ii) to propose scheme scenarios and to test respondents' preferences for possible alternatives.

Three different questionnaires were designed and submitted to the three categories of respondents. Each questionnaire was structured into four sections: (1) the characteristics of the respondent and the entity (farm, company, community), their relationship to the environment and climate mitigation strategies, (2) their knowledge of hedgerows and the carbon market, (3) their preferences towards different possible systems, evaluated on the basis of a set of cards based on the Discrete Choice Experiment (DCE)[57] method, and finally (4) the reasons for their preferences according to the different attributes of the system. The first three themes were mainly addressed through closed questions, the fourth was mainly addressed through open questions.

Several analytical methods were used to process the data collected. They consisted of statistical analyses of quantitative and qualitative data (AFCM, discrete choice methods) and qualitative analyses of responses to open-ended questions.

A sampling of respondents affected by hedgerows or the climate

The aim of this sampling method was to test the possibility of creating a carbon market and its potential characteristics, even though the respondents were more inclined to engage in the scheme.. We,

[57] A method introduced by Louvière (1983) in environmental economics to assess the value of a property via its attributes or characteristics.

therefore, constructed reasoned sampling based on two criteria for farmers (belonging to the study areas and prior participation in bocage or agri-environmental projects), two criteria for companies (link to the target territories, and commitment to a diagnosis or carbon offset approach), and two criteria for local authorities (link to the target territories and field of activity: agriculture, climate energy or environment). We sought to favour respondents who had initiated climate or agro-environmental initiatives in these three categories of respondents.

Table 1: *Distribution of the sample by study area*

Territories	Farmers	Companies	Local Authorities
Pays des Mauges	18	9	4
Pays du Roi Morvan	16	2	5
Pays de la Vallée de la Sarthe	10	1	3
Outside territories	1	10	9
Total	**45**	**22**	**21**

The farmers surveyed are mainly male (91%), aged around 50 years old with education levels varying between secondary school and higher education. Farms have an average agricultural area (UAA) of 107 ha. A third of the respondents have obtained organic certification and more than 77% of them have already participated in other environmental schemes (AEM, tree planting program etc.). This sample therefore corresponds to farms larger than the average in Western France (about 65 ha in Brittany and Pays de la Loire in 2017), and farmers more involved in environmental schemes (about 8% of farms are AB certified in these same regions in 2017).

The sample of companies is dominated by males (68%), relatively young (41% are under 40 years of age) with high levels of education (Masters degree level represents 68% of the respondents). The companies surveyed are divided between SMEs (nearly 41% or 9/22), FTEs (36%) and large companies (22%). There are no microenterprises with less than 10 employees. This sample therefore over-represents medium to large companies at the expense of companies with less than 10 employees. Indeed, at the national level, 96% of companies, excluding financial activities and insurance, are microenterprises, while large companies represent less than 1% of them (Insee, 2017). More than 80% of the companies surveyed say they have carried out a diagnosis of their greenhouse gas emissions and undertaken actions to reduce their carbon footprint.

The sample of local authorities is composed of 10 elected officials and 11 agents. They are in charge of energy, sustainable development or climate issues (33% of them) or involved in agricultural and agri-food issues (33%). They are elected or agents of the intermunicipalities of the survey areas, of the municipalities, or for a third of them, of other communities (nearby agglomerations, departmental councils). They are mainly male (71%). The levels of education are generally high since a Masters degree represents more than half of the sample. More than 60% of the local authorities surveyed did not carry out a greenhouse gas (GHG) emissions diagnosis, but 60% of the local authorities carried out a bocage diagnosis, which illustrates the interest shown in bocage hedgerows.

Survey areas characterized by the density of hedgerows, the pre-existence of hedgerow projects and the importance of livestock farming.

The three territories surveyed are included in the two regions of Brittany and Pays de Loire. These territories were chosen for their determination on energy and climate transition issues, which is reflected in the fact that these three have set up a Climate Local Policy, but also for their longstanding work on bocage and carbon storage. Agriculture is very important in these three rural territories with important production capacities. Production is generally oriented towards livestock (mainly dairy farming), poultry and pig farming (Table 2).

***Table 2**: Summary of territory characteristics studied*

Territories	Pays des Mauges	Pays du Roi Morvan	Pays de la Vallée de la Sarthe
Number of residents	121 000	26 500	78 000
Surface Area (km²)	1 315	763	1 104
UAA (utilized agricultural area) in ha	141 5980	43 801	413 900
Hedgerows length (km) (in 2011)	10 343	4 314	5 098
production orientation	Livestock farming	Livestock farming	Livestock farming
Policies in place	-Circular economy - Territorial Climate-Air-Energy Plan, initiated in 2003 -PAT (territorial food program)	- Territorial Climate-Air-Energy Plan initiated in 2010 - Hedgerow plantation programs (2003-2006 and 2011-2013)	- Territorial Climate-Air-Energy Plan initiated in 2009 - CEP (Shared Energy Advisor)

Results

High commitment linked with different views of local carbon markets

The first challenge of our survey was to measure the interest of the respondents in a local and voluntary carbon market scheme. Although we had chosen respondents a priori concerned with maintaining hedgerows or with climate change issues, (which would tend to increase interest in our proposal), many of these respondents had already invested in hedgerow plantations or climate change systems (more than three-quarters of them). It was therefore, far from certain that they would be interested in testing a new type of mechanism.

After describing the characteristics and main features of a local carbon market for hedgerows, we asked them: *"Would you be willing to engage in this type of scheme?".* Nearly 80% of respondents want to get involved, regardless of the type of individuals involved.

The motivation behind the respondents' commitment highlights the signification of such a scheme Local authorities see this scheme as a way to increase support for hedgerows preservation. The multiple advantages of the scheme, particularly in terms of ecosystem services (preservation of biodiversity and landscape quality, and therefore quality of life), appear to influence their commitment. Local authorities also underline the importance of these schemes in relation to stakeholders who are encouraged to engage in climate and environmental issues, and in order to generate added value for the territory itself. These respondents more often project themselves as intermediaries in the market, only a third imagine themselves as intermediaries and buyers of carbon credits. For companies engaging in a carbon offset market, this allows them to be part of a virtuous environmental approach and to establish their territorial anchorage, in addition to economic interests and positive spinoffs in terms of the company's image. Farmers mainly see it as an opportunity to better remunerate hedgerow maintenance, which many already do. Some are also motivated by environmental and climate ambition, by the possibility of increasing their social recognition, and to improve their hedgerow management. Respondents who are hesitant or unwilling to engage in this scheme mainly say they lack information on the scheme (cost, relevance, interests, actors involved) in order to be able to give their opinion.

A shared ambition to combine different environmental benefits: carbon storage, biodiversity, water quality, landscapes.

The objective in these voluntary markets would of course be carbon sequestration. However, the definition of this objective can be clarified according to different dimensions, including the consideration of environmental co-benefits and the inclusion in the contract of requirements concerning the practical modalities of carbon sequestration.

We have chosen to measure respondents' preferences for different qualities of carbon credits through three indicators:

Affiliation to environmental co-benefits was measured by assessing the preferences of respondents between two types of hedgerow: mixed hedgerows are presented as hedgerows that moderately store carbon, but generate multiple environmental co-benefits (biodiversity, landscape, water purification, erosion control) and coppice hedgerows are presented as those which store more carbon but generate fewer environmental co-benefits.

- The duration of farmers' commitment (5, 15 or 30 years),

- The proportion of hedgerow length managed by the farmer: either all the hedgerows present on the farm, or part of his hedgerow length, with the possibility of changing them (moving, grubbing up, replanting).

Our survey shows a strong preference, from all types of respondents, for hedgerows with environmental co-benefits. 71% of respondents say they prefer this modality when only 11% say they prefer coppice hedgerows. This preference is supported by the statistical analysis of the DCE (Discrete Choice Experiment). For all types of respondents, this preference is explained by the perceived importance of other environmental issues: biodiversity in particular for companies, water in particular for local authorities, aesthetics and biodiversity for farmers. Preference for mixed hedgerows is also linked to the desire to maintain existing types of hedgerows on farms or in the area and to implement previous hedgerow projects or policies (communities, farmers). Finally, farmers are interested in the economic co-benefits associated with mixed hedgerows: wood production and valorization.

Preferences are more heterogeneous with regard to the duration of the engagement and hedgerow length to be managed. A small majority of respondents prefer a 15-year commitment period, with very mixed responses for hedgerow length. We can thus distinguish four types of preferences concerning the contract objective.

- **The whole length of a mixed hedgerow:** The aim here is to support the creation or improvement of mixed hedgerows, during a 15-year contract which covers the entire length of a farmer's hedgerow. This contract is in line with previous projects and practices. For these respondents, it is a question of proposing a contract that is consistent with the ambition of storage in the medium or long term, with hedgerow maintenance cycles. The commitment of the entire length is a guarantee of maintaining hedgerows (for local authorities) and securing the scheme (for companies), whose main fear is that farmers will continue to pull up trees. Farmers consider that it is coherent and interesting to think globally about the management of hedgerows on their farm, and that the commitment of the entire length is a guarantee of administrative simplicity.

- **Flexibility concerning mixed hedgerows:** here too, it is a question of giving priority to the creation or improvement of mixed hedgerows, but this time the respondents prefer 5 or 15 year contracts and give priority to the possibility for farmers to lease only part of their hedgerow length or to be able to move the committed hedgerows. The aim is to enable farmers to commit themselves in stages, to test the scheme, but also to adapt it to changes on their farm, by allowing adjustments to the contractualised hedgerow length and by maintaining a certain freedom to manage their entire hedgerow length. This is the preferred contract for all categories of respondents. However, companies highlight the importance of implementing precise control over hedgerow length developments.

- **Strong commitment regardless of the type of hedgerow:** respondents who prefer a long contract tend to also prefer a total commitment of the hedgerow length. Farmers who prefer these contracts also want to create new hedgerows and not just improve on or manage existing ones. Respondents think it would be desirable to propose a highly engaging scheme to strengthen its credibility (companies, local authorities) and its impact in the fight against climate change. Farmers also underline that they do not plan to remove hedgerows, with or without contractualization. Finally, some mentioned the environmental challenge of maintaining ecological continuity, which justifies the use of the whole hedgerow length.

- **Partial coppicing:** this fourth type of contract is the only one that favours coppice hedgerows, over commitment periods of 5 or 15 years and management of only part of thehedgerow length. For these respondents, the challenge of rapidly storing carbon is a priority and in this respect justification lies in supporting the most efficient hedgerows only. For farmers, it is also the contract that appears to be the most profitable. In any case, the flexibility of the length of hedgerow system used makes it possible to adapt to the challenges facing farms, but also to other measures to fight climate change that could be developed, such as land exchange.

For the three variables tested, the level of indecision (cumulative non-response and "don't know" responses) is high, particularly for the sub-population of local authorities. Respondents explain that they do not feel competent to arbitrate, or that they consider that farmers should be given the choice to adapt as best they can to their situations. It also concerns respondents who are not interested in the scheme (farmers, local authorities).

Tab 3: *Preferences for contract types according to the respondents surveyed*

	Farmers		Local authorities		Companies		Total	
	Eff.	% Obs.	Eff.	% Obs.	Eff.	% Obs.	Eff.	% Obs.
The whole length of a mixed hedgerow	16	36,40%	2	10%	3	13,60%	21	24,40%
Flexibility concerning mixed hedgerows	15	34,10%	10	50%	8	36,40%	33	38,40%
Strong commitment regardless of the type of hedgerow	6	13,60%	1	5%	4	18,20%	11	12,80%
Partial coppicing	2	4,50%	2	10%	4	18,20%	8	9,30%
Undecided	5	11,40%	5	25%	3	13,60%	13	15,10%
Total	44	100%	20	100%	22	100%	86	
p-value = 0,13 ; Khi2 = 12,41 ; ddl = 8,00								

These preferences are different according to respondent type (Tab3). In particular, it should be noted that company preferences are more dispersed than for the other cate gories and that more community respondents are willing to give farmers some flexibility.

Four preference categories relating to the socio-economic attributes of the scheme

We hypothesized that the conditions under which the voluntary carbon market mechanism was organized influenced the respondents' desire to engage in it and their willingness to pay or receive. We therefore asked the various respondents to give us their opinions on a set of possible scheme characteristics: the nature of the intermediate actor within the market and the methods of control, but also traceability (in a "traced" market, buyers identify carbon as coming from a group of farmers in a given area, and in return, these farmers know their buyers and each of the stakeholders), the possibility of benefiting from technical support, the nature of carbon credit certification and finally the way the price is constructed (indexed to another carbon market, at hedgerow maintenance cost or not indexed).

Respondents generally agree on the interest of implementing a traced market. 71% prefer this modality compared to only 8% who prefer an untraced market. Local authorities and companies underline the importance of traceability in creating links between buyers and sellers, facilitating the monitoring and control of the action and making it possible to communicate with employees or customers of companies, by directly involving farmers. For farmers, this facilitates local recognition of their commitment to climate change issues. Some farmers prefer an untracked market. In this case, they consider that traceability is unnecessary since, on the contrary, the aggregation of carbon credits at a regional or national level makes it possible to simplify the scheme, reduce transaction costs or facilitate access to the market.

For the other characteristics, the preferences appear more contrasted, we distinguish four desirable profiles:

Local development system. The voluntary market would strongly involve a local organization as a central actor in its governance. Control could mobilise buyers and sellers through a participatory guaranteed system. As the aim of the scheme is to support better management of hedgerows, it seems important here that there be technical support and that the price paid to farmers be indexed to the costs of maintaining the hedgerow.

- OTC contracts between companies and farmers in a simple and inexpensive system. To implement a local carbon market, it must be simplified. Systematically, these respondents prefer uncomplicated forms of governance (no certification, no technical support), the preference is oriented towards a direct contractualization between companies and farmers and for this a link to a private intermediary is appropriate.

- National aggregated environmental public policy scheme. The local roots of the market and its traceability are of little importance to these respondents. The focus is on ensuring the implementation of reliable and credible storage practices, including certification and technical control. The State appears to be the right intermediary for this mechanism.

- A local supply traced within the international carbon market. For these respondents, the voluntary carbon markets resulting from hedgerows must be able to integrate into international markets. To do this, the price must be indexed to international prices. Nevertheless, companies want to be able to buy locally and farmers want to rely on a local collective and make their area and region benefit from the scheme. Finally, these respondents are concerned about the credibility of the system: for this, they prefer a control that doubles the photo-interpretation of a technician's visit, they are committed to setting up a reliable and serious certification system (international or national).

Table 4: *Preferences of the different categories of respondents according to scheme type*

Acteur	Farmers		Local Authorities		Companies		Total	
Classe	Eff.	% Obs.	Eff.	% Obs.	Eff.	% Obs.	**Eff.**	**% Obs.**
Local development system	15	34%	**16**	**80%**	8	36%	**39**	**45%**
OTC contracts	8	18%	4	20%	8	36%	**20**	**23%**
local supply within the international carbon market	10	23%	0	0%	5	23%	**15**	**17%**
National public policy scheme	**11**	**25%**	0	0%	1	5%	**12**	**14%**
Total	**44**	**100%**	**20**	**100%**	**22**	**100%**	**86**	
p-value = < 0,01 ; Khi2 = 21,70 ; ddl = 6,00								

The stakeholders' preferences for these different types of schemes are very much shared, particularly for companies and farmers (Table 4).

Discussion - conclusion

Our research aimed to test the opportunity to implement voluntary carbon markets to support the maintenance of hedgerows, in a context where a diversity of bocage support systems already exist (at national and local scales). It then aimed to clarify the form that these contracts could take.

A market involving a set of environmental services

The first significant result is that most of the respondents surveyed are interested in this type of measure. They prefer to enter a market that values mixed hedgerows. This result should be considered with caution as it concerns a statement of prospective intent and is based on a selected sample of respondents interested in our objective. Nevertheless, this result is confirmed by the analysis of the Choice experiment associated with this survey, which succeeds in identifying a potential price range for trading carbon credits from hedgerows; then by the results of the three focus groups according to the territories, in which the respondents have highlighted that they are ready to commit to the establishment of local carbon markets.

The interest in this new device is based on a diversity of motivations (technical, economic, environmental and social), which reflect the differences in the points of view of the stakeholders interviewed. However, for the majority of them, the scheme should promote hedgerows which produce a diversity of ecosystem services (ecological, landscape, water-related), even if this means limiting the efficiency of the service in terms of carbon storage. This reflects a desire to integrate this scheme into the continuity of prior commitments (local authority policies, agricultural practices). Stakeholders thus participate in a form of erasure of the climate objective in the face of the ambition of environmental coherence, which constitutes a way of managing environmental injunctions which is often seen as contractictory by the respondents (Thareau et al., 2014). Stakeholders, and in particular farmers, also participate in strengthening inertia in regard to local action, which is traditionally observed in public policy analyses (Bertrand, 2013). It should be noted that it is within companies that we encounter the highest number of respondents concerned about the climate efficiency of the scheme, even if it means transforming local landscapes and practices. Less rooted in agri-environmental schemes, companies can be drivers of transformation in local practices.

A variability of preferences related to contract

Our results distinguish four types of preferences regarding the objective of the contract. The contract which is preferred by all types of respondents, is flexible (in terms of duration of engagement and hedgerow length engaged), this result correspondswith research conducted on farmers' commitment to agri-environmental schemes (Ruto and Garrod, 2009; Espinosa-Goded et al., 2010; Christensen et al., 2011). We assumed that preferences for short and flexible contracts would be more asserted by farmers than by buyers or local authorities. However, we observed the opposite: farmers, more than other types of respondents prefer binding contracts. Companies and especially local authorities prefer more flexible contracts. The farmers' point of view is explained on the one hand by the fact that the majority of them have already developed important hedgerow lengths and the scheme would make it possible to finance pre-existing practices; on the other hand, they wish to ensure the credibility and robustness of the market via the terms of the contract while limiting the administrative complexity of the scheme (this ambition of administrative simplicity is in accordance with the literature). On the other hand, companies and local authorities see the scheme as leverage to engage new farmers in the implementation of hedgerows, by proposing conditions of engagement that allow them to test the market. This enables the facilitaion and enrolment of the highest possible number of farmers thus increasing the effectiveness of the scheme. From their point of view, the credibility of the market must be ensured by the attributes of the scheme.

A variabilty of preferences in relation to the scheme

Our research identifies four forms of schemes which are desirable from the respondents' perspective. Except for local authorities who largely prefer a "local development system" type, in which they would play a decisive role in the governance of the scheme, the other respondents have more fragmented preferences. They are partially linked to the respondent's experiences: farmers are more interested than others in schemes characterised by high intermediation that provides technical support and robust public certification of the effectiveness of the environmental service. These scheme attributes resemble the AEMs largely mobilized by these farmers. Companies prefer market driven or OTC contractual mecahnisms which are easily integrated into their business practices. The compatibility of the scheme with system, values and practices, in addition to respondent experience, helps to explain their preferences (Gherib, 2006; Spence et al, 2007)

What is at stake in repondents' preferences is the way in which trust between the parties and the credibility of the scheme are organised: via a direct and local link in local and over the counter development schemes, or via national or international institutions in the international and national market schemes. What is also at stake is the efficiency and cost of the scheme. Some respondents prefer to limit these costs and mainly pay for the ecosystem service itself, whereas others believe that the success of the device will rely on a consistent investment in governance tasks, which could be partly suypported by public investment via local authorities' budgets. Finally, the respondents' preferences also reflect visions of the system's anchoring in political strategies at different scales: at the level of companies only (willingly), in the context of territorial projects (local development) or finally in relation to national policies, created or not created in the context of the COP (national mechanism and international market). This anchoring contributes to the legibility and recognition expected, particularly from farmers.

Surprisingly, the objective to find new connections between farmers and enterprises in a local and communitarianism scheme seems more affirmed by companies than by farmers. With regard to companies; firstly, it is motivated by the ambition to control the implementation of storage measures; secondly to be able to report, in particular to their employees, on the company's territory-specific commitment; and finally, by the desire to strengthen commercial relationships with their suppliers (Tronquet et al., 2017).

Inertia and renewal of transitional measures towards agro-ecology

Our research aims to suggest the development of an innovative scheme for the valorization of ecosystem services. However, it also highlights a certain inertia in the preferences of farmers and of local authorities (with regard to the objective and mechanisims of the scheme). In this proposed scheme, companies are new players. With them, two major challenges are affirmed: the desire to anchor the system in the territories via direct links between buyers and sellers and the ambition of measurable climate efficiency. These ambitions are factors for renewal and social innovation in a context of a profusion of agri-environmental measures to maintain hedgerows. These local carbon markets could make it possible to create mixed workspaces in the evolution of agricultural models and practices, which mobilize new stakeholders (companies), and which seem to be able to contribute to improving knowledge and recognition of the role of farmers in their territories.

Aknowledgements

This research has been conducted as part of the Carbocage project (2016-2020) led by the Chambre d’agriculture des Pays de la Loire and financed by ADEME.

References

ADEME. 2015. « Réintégrer l’arbre dans les systèmes agricoles ». Agriculture et environnement: des pratiques clefgs pour la préservation du climat, des sols et de l’air, et les économies d’énergie 6.

ADEME. 2016. « Elus, l’essentiel à connaître sur les PCAET ». ADEME Éditions. https://www.ademe.fr/sites/default/files/assets/documents/elus_l_essentiel_pcaet_2016_ref_8832.pdf.

Bertrand F. (2013) L’institutionnalisation locale des politiques climatiques en France., in: *Les territoires face aux changements climatiques. Une première génération d’initiativeslocales,* Bertrand, F. and Rocher, L. (éds.), Peter Lang, 25-71.

Cabagnols, Alexandre, et Christian Le Bas. 2006. « Les déterminants du comportement de Responsabilité sociale de l’entreprise. Une analyse économétrique à partir de nouvelles données d’enquête », 25.

Chenost et al, Clément. 2010. « Les marchés du carbone forestier ».

Christensen, Tove, Anders Branth Pedersen, Helle Oersted Nielsen, Morten Raun Mørkbak, Berit Hasler, et Sigrid Denver. 2011. « Determinants of Farmers’ Willingness to Participate in Subsidy Schemes for Pesticide-Free Buffer Zones—A Choice Experiment Study ». *Ecological Economics* 70 (8): 1558‑64.

Espinosa-Goded, Maria, Jesús Barreiro-Hurlé, et Eric Ruto. 2010. « What Do Farmers Want From Agri-Environmental Scheme Design? A Choice Experiment Approach ». *Journal of Agricultural Economics* 61 (2): 259‑73.

Follain, Stéphane, Christian Walter, Arnaud Legout, Blandine Lemercier, et Gilles Dutin. 2007. « Induced Effects of Hedgerow Networks on Soil Organic Carbon Storage within an Agricultural Landscape ». *Geoderma* 142 (1): 80‑95.

Gherib.J et Sandrine .B. 2008. « L'engagement environnemental des PME : Une analyse comparative France Tunisie ».

Labelle, François, et Josée St-Pierre. 2010. « Les déterminants institutionnels, organisationnels et individuels de la sensibilité des PME au sujet du développement durable », 17.

Lacoste, M., V. Viaud, D. Michot, et C. Walter. 2015. « Landscape-Scale Modelling of Erosion Processes and Soil Carbon Dynamics under Land-Use and Climate Change in Agroecosystems ». *European Journal of Soil Science* 66 (4): 780‑91.

Lockie, S. (2013). "Market instruments, ecosystem services, and property rights: Assumptions and conditions for sustained social and ecological benefits." *Land Use Policy* 31: 90-98.

Louviere, J., et G. woodworth. 1983. « *Design and Analysis of Simulated Consumer Choice or Allocation Experiments: An Approach Based on Aggregate Data - Jordan J. Louviere, George Woodworth, 1983* », 1983.

Mariola, M. J. (2012). "Farmers, trust, and the market solution to water pollution: The role of social embeddedness in water quality trading." *Journal of rural studies* 28(4): 577-589.

McCollin D. (2000) Editorial: Hedgerow policy and protection—changing paradigms and the conservation ethic, *Journal of Environmental Management* 60, 3-6.

Pellerin S. and Bamière L. (2013) Quelle contribution de l'agriculture française à la réduction des émissions de gaz à effet de serre? Potentiel d'atténuation et coût de dix actions techniques., INRA.

Ruto, Eric, et Guy Garrod. 2009. « Investigating farmers' preferences for the design of agri-environment schemes: a choice experiment approach ». *Journal of Environmental Planning and Management* 52 (5): 631‑47.

Siebert, Rosemarie, Mark Toogood, et Andrea Knierim. 2006. « Factors Affecting European Farmers' Participation in Biodiversity Policies ». *Sociologia Ruralis* 46 (4): 318‑40.

Schirpke, U., D. Marino, et al. (2017). "Operationalising ecosystem services for effective management of protected areas: Experiences and challenges." *Ecosystem Services* 28: 105-114.

Spence et al. 2007. « Développement durable et PME: Une étude exploratoire des déterminants de leur engagement ». *Revue internationale P.M.E.: Économie et gestion de la petite et moyenne entreprise* 20 (3‑4): 17.

Thareau B. and Billaud J.-P. (2014) Transformation des mondes agricoles locaux autour d'une redéfinition de l'appartenance territoriale. In SFER (ed.), *Le Foncier Agricole : usages, tensions et régulations* Lyon.

Thareau B. and Fabry M. (2013) Actions foncières au nom de l'environnement : des élus locaux interviennent dans l'évolution de l'agriculture, in: *Terres agricoles périurbaines : une gouvernance foncière en construction*, Bertrand, N. (ed.), Versailles, Quae, 135-154.

Thareau B., Fabry M. and Robin A. (2014) Lutter contre le changement climatique ou pour son identité professionnelle ? , *Vertigo - La revue en sciences de l'environnement* 14, 3.

Tronquet C., Grimault J. and Foucherot C. (2017) Potentiel et déterminants de la demande volontaire en crédits carbone en France, I4CE.

Viaud V. and Gautier P. (2019) Potentiel de stockage carbone des haies bocagères de l'Ouest de la France. Rapport de recherche Carbocage., Chambre d'Agriculture des Pays de la Loire, Ademe, INRA.

MAKING THE AGROECOLOGICAL TURN: IDENTIFICATION OF FARM-LEVEL SOCIOTECHNICAL ADOPTION FACTORS AND DETERMINANTS

Anda Adamsone-Fiskovica, Mikelis Grivins

Baltic Studies Centre, Latvia

Abstract: The European Green Deal, which strives to move towards environment- and climate-friendly farming, stipulates a number of agroecological measures to reach this ambition. Some of the proposed technologies include intercropping, catch-crops, and green manure application on farms, which are practically feasible for the introduction of sustainable soil management in horticulture. However, until now their uptake has been quite limited despite the demonstrated effectiveness.

The current research aims to systematically review the current state of the art of research and knowledge with regard to the factors that influence the adoption or non-adoption of the selected technologies by farmers. The search of peer-reviewed articles published in 2010-2020 was carried out in the Scopus and Web of Science databases. Based on a set of keywords, a total of 122 unique articles were retrieved for initial scanning for relevance, with the list subsequently narrowed down to 63 articles retained for full-text reading.

There has been a gradual increase in the number of articles addressing the adoption of the selected technologies over the decade. In terms of the geographic scope there is a considerable lack of studies from Europe, with the majority covering Africa and Asia, as well as the USA. The selected technologies are mostly addressed with reference to conservation agriculture, best management practices, climate-smart agriculture, sustainable intensification, and organic agriculture. While there is a general lack of theory-guided studies, the most frequently used ones are the Theory of planned behaviour and the Diffusion of innovations theory. Empirical data collection methods cover a mix of qualitative and quantitative methods, yet these are dominated by semi-structured or structured surveys focusing on the correlations between the adoption and a set of variables.

Some of the initial observations show that factors studied by researchers include a diverse range of internal and external ones spanning across agronomic, economic, technological, environmental, political, social and psychological domains. While mostly the focus is on farm characteristics such as farm size, land tenure, livestock ownership, irrigation system, soil quality, fertilizer use, as well as labour force, income sources, loans/debts, along with farmer traits such as age, gender, education, farming experience, employment status, there are studies also highlighting the role of farmer's objectives, motives, orientations, risk attitude, aesthetic values, cultural preferences, and social participation. Other explored factors include information sources, availability inputs and credit, distance to market, access to extension services, presence of policy incentives, not to mention place-specific climate and weather conditions.