Socio-economic drivers of coexistence of landraces and modern crop varieties in agro-biodiversity rich Yunnan rice fields

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Analysis

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ABSTRACT

This paper investigates a situation of coexistence of landraces and modern crop varieties for market-oriented production in the Yunnan rice fields in China. Through a fieldwork survey of an experiment by the government with the introduction of modern varieties in traditional villages, the paper shows that landraces and modern crop varieties can co-exist. The analysis shows that the major features that play a role in the choices made by the individual farmers between modern crop varieties and landraces are not the agronomic conditions, although they certainly play a role, but economic and social drivers. The results of the analysis allows a better understanding of the distinct socio-economic drivers and impacts of each of the production systems. The latter can provide insights for policy strategies aimed at promoting agrobiodiversity rich landscapes in situations of co-existence of heterogeneous socio-technical production systems.

1. Introduction

Several studies in agroecology show that the introduction of greater cultivated biodiversity in agricultural landscapes allows more environmentally sustainable agriculture based on fewer pesticides (Zhu et al., 2000; Mundt, 2002a, 2002b; Keesing et al., 2006). The use of more genetically diverse seeds for a given species reduces the severity and frequency of diseases via genetic dilution effects of populations of virulent pathogens (McDonald and Linde, 2002; Goyeau and Lannou, 2011; De Vallavieille-Pope et al., 2012). On the other hand, throughout the world, traditional diverse agricultural landscapes have been replaced by monocultures of specialized varieties that have high yields and high known commercial potential, but which demand a higher input of pesticides and fertilizers (Kontoleon et al., 2008). This development model, in spite of its many positive outcomes, reduces the spectrum of cultivated biodiversity by prioritizing the genetic improvement of the specialized varieties (Cleveland and Solieri, 2002; Bonneuil and Demeulenaere, 2007; Bonneuil and Thomas, 2009; Coolsaet, 2016).

In reaction to the limits of the use of modern varieties, there is currently a resurgence of farm seed exchange organizations with landraces (Prip and Fauchald, 2016; Galluzzi et al., 2010; Coolsaet, 2016). Such landraces are domesticated wild varieties that are obtained through increasing the frequency of the desired phenotypic properties through on field selection (Lipton and Longhurst, 2010). The landraces have clearly identifiable phenotypic characteristics, but are more genetically diverse than seeds of modern varieties (Villa et al., 2005). The farm seed exchange organizations allow the continuous farmer led selection of seeds, by relying on a variety of non-market mechanisms such as gifts, social reciprocity networks and shared infrastructure resources.

To understand the potential opportunities and barriers for the preservation of such diverse agro-ecological landscapes, this paper analyses a situation of coexistence between seeds of landraces and modern crop varieties in the Yunnan rice fields in China. More specifically, through analysing an experiment by the government with the introduction of modern varieties in traditional villages, the paper investigates if the maintenance of agroecological production systems with landraces, in spite of the introduction of improved "market ready" seeds of modern varieties, is possible.

The production systems are analysed through adopting a socio-technical systems lens on the farmers' choice of seed varieties (cf. Vanloqueren and Baret 2008 and 2009), with the view to highlight the relationships between technical and socio-economic elements, such as social norms, economic strategies and crop management practices amongst others. Following the seminal work by Kemp et al. (for instance Rip and Kemp, 1998) and the more recent overview in the work of Geels (2005), this socio-technical system can be defined as "a relatively stable configuration associating institutions, techniques and

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artefacts, as well as rules, practices and networks of actors" (Rip and Kemp, 1998). Rules in socio-technical systems can be both formal and informal. They can be embedded in cognitive frameworks, social norms, or technical procedures, such as in informal rules for seed exchange or community water irrigation arrangements. Social practices include both practices amongst humans and the relationships between humans and nature. Such practices around "relational values" (Chan et al., 2016) can take the form of stewardship for landscape elements that support cultural practices such as food habits or maintaining crop genetic diversity for building of resilience in the face of variable climatic conditions (Wang et al., 2016; Niekerk and Wynberg, 2017; Roesch-McNally et al., 2017). The characteristics of the rules and practices within socio-technical systems affect the way people organize themselves and the nature of their work (Mak, 2001).

The paper is structured as follows. The next section (Section 2) briefly introduces the contemporary research on synergies between market and non-market coordination mechanisms. Section 3 presents an overview of the co-existence of modern and traditional seed selection and production systems in the area of study. The third section presents the data collection and the methodology that was used in the fieldwork. Sections 5 and 6 present and discuss the results.

2. Creating synergies between market and non-market coordination mechanisms

Maintaining production systems based on the use of landraces, in combination with the adoption of modern varieties, can provide important benefits to the community.

On the one hand, the agro-ecological performance of the agro-ecosystems mentioned above, in terms of disease management and landscape preservation, is an important motivation for adopting biodiversity rich production practices. Further, diversified agroecological production systems are well placed to serve local markets and contribute to regional food security (Wittman et al., 2017). In addition, social groups have different culinary preferences and different rituals involving agricultural production. The choice for diverse production systems also reflects their attachment to the typicality of local agricultural production and food consumption habits (Bellon, 1996; Brush and Meng, 1998; Nautiyal et al., 2008; Wang et al., 2016; Pascual et al., 2017).

On the other hand, yield improvement is a key concern of the communities, which strive for economic sustainability. Indeed, the shift towards modern varieties by traditional communities is mainly based on economic motives. Extreme poverty and high biodiversity are often geographically coincidental (Chappell et al., 2013), and it is not sustainable to reach biodiversity objectives without attending to the legitimate aspirations of local human populations for reasonable standards of living (see Barrett et al., 2011). The introduction of seeds of modern varieties and an agricultural market, if it does not eliminate traditional seeds and seed exchange, allows access to a money market and improves the income of the populations, while preserving some social demands for the traditional crops (Brush and Meng, 1998). Therefore, the coexistence of traditional and modern types of socio-technical systems is a possible pathway to preserve socio-cultural diversity, while meeting the standardized needs of the mass market (Brush, 2005; Orozco–Ramírez et al., 2014).

From an institutional view, the coexistence strategy is based on a combination of market mechanisms (necessary for the improvement of agricultural income through sales) and non-market mechanisms (necessary for the maintenance of cultural diversity, local typicality and the informal seed exchange mechanisms). Scholars in comparative institutional analysis characterize such a situation as polycentric organisational systems (Ostrom, 2005). Polycentric systems are composed of for-profit, nonprofit, and government providers that occupy different roles in a same production environment (Benkler, 2006; Grabowski and Hirth, 2003; Becchetti and Huybrechts, 2008; Goering, 2008).

Various theories have analysed the existence of profit and nonprofit organisational forms within a given polycentric organisational system (Weisbrod, 1998; Salamon, 1995). These studies can be summarized via their focus on three modes of coexistence:

2.1. Avoidance and stratification

Studies show that in some cases polycentric systems may contain two types of strata in which different organizations and consumers operate. This is the case of stratified markets (Marwell and McInerney, 2005). In this configuration, coexistence takes the form of avoidance between the two institutional forms. The consumer population is divided in two: the market and the non-market organizations serve distinct consumer groups (McInerney, 2012; Fox Garrity et al., 2011).

2.2. Competition

Most of the existing literature focuses on the competitive relationship between market institutions and non-market institutions considering them as competing for the provision of the same products and services (Schiff and Weisbrod, 1991; Bagnoli and Watts, 2003). This is the case where there is a competition between providers of market goods and providers of non-market goods. In some cases, this competition seems to lead to the disappearance of one or another of the institutional forms (Marwell and McInerney, 2005).

2.3. Coopetition and mutual influence

In this third mode, co-existing market and non-market institutions interact in the same social fabric and their relations are therefore complex. Research has pointed out that sometimes market and non-market organizations maintain in the same time competitive and cooperative relationships (Abzug and Webb, 1999; Becchetti and Huybrechts, 2008). Indeed, studies show that competitive market organizations and non-profit organizations collaborate when they become aware of a common interest (O'Regan and Oster, 2000; Galaskiewicz and Colman, 2006). Beyond cooperation, Huybrechts et al. (2006) show that, even if each institutional form remains distinct, sometimes one form integrates organisational features of the other form. The latter might lead to organisational improvements based on mutual influence.

These studies on the dynamics and functioning of polycentric organisational networks underline the complexity but also the fragility of the coexistence of different institutional forms in the same sector. In the case of in situ agro-biodiversity conservation, a coexistence configuration seems a promising avenue to maintain a wide range of cultivated biodiversity, while at the same time improving income and living conditions for local populations (Fischer et al., 2008). However, finding the optimal strategy depends not only on the epidemiological and agronomic parameters, but also on the socio-economic and agro-ecological drivers of change from one production system to another. Therefore, to better understand the barriers and options to coexistence of landrace based and modern variety production systems, this paper will analyse the combination of agronomic, agro-ecological and socio-economic factors that determine the choice of individual farmers to adopt certain crop production systems.

3. Mosaic of modern varieties and rice landraces in the upland Yunnan rice terraces

The case study in this paper focuses on the Yuanyang County located in the Honghe Hani Yi Autonomous Prefecture in the south-eastern Yunnan province in China. This area is both a hot spot of minority cultures (Harrell, 2001; Yang et al., 2004; Xu et al., 2009) and biodiversity (Mackinnon et al., 1996; Mittermeier et al., 2005). The Food and Agriculture Organization (FAO) has designated the Yuanyang County as a "Globally Important Agricultural Heritage System" in 2010 and the United Nations Educational, Scientific, and Cultural Organization (UNESCO) listed the County as a World Cultural Heritage site in 2013.

The Yunnan rice terrace system is a traditional system that is at least 1300 years old (Yuan et al., 2014). The region has a long history of farmers' breeding based on seed exchange and specific traditional ecological knowledge. These practices have resulted in a remarkable rice genetic diversity, both in term of the presence of rare rice species and of species richness. For instance, Jiao et al. (2012) estimate that there are at least 195 local rice landraces and 47 wild rice varieties in this area. In addition, the rice terraces have a relatively high production for a mountain region, estimated around 4 to 6/T per ha in the areas between 1400 and 1900 m (He et al., 2011; Fullen et al., 2017), and very low disease incidence.

The traditional production system in the area is historically centred on agroecology. It is based on a synergy between "Forests–Village–Terrace–River" (Feng et al., 2008) and a combination of rice fish and duck production (Zhang et al., 2017). This traditional system has proved to produce multiple ecosystem services, such as flood disaster mitigation, soil and water conservation and soil improvement (Jiao et al., 1999; Yuan et al., 2014), in addition to contributing to pest and weed control (Zhang et al., 2011). The survey of Zhang et al. in 2017 in the Honghe Prefecture shows that the rice-fish-duck production is still very present in the area, although the opportunity cost from other income raising activities puts a high pressure on the system (Zhang et al., 2017).

The use of landraces plays a key role in farming system in this area. Beyond the genetic richness of the various landraces, the system is characterized by a local diversity in production methods of the spatially scattered plots of the farms fields. For instance, in order to equally allocate the water and the distance from field to house, each family has plots in the upstream, the middle and the downstream of the village rice terrace. Combined with planting of many diverse rice cultivars, this scattered landscape leads to a mosaic of farm plots with a network of green corridors providing a large range of habitats for organisms, including both beneficial and pest species. This mosaic configuration of diverse varieties mitigates the risk of propagation of a single or dominant pest (Zhu et al., 2000 and 2003; Yang et al., 2009; Jiao et al., 2012).

The Yuanyang was for a long time a relatively isolated region. In the last decades, the state provides services such as roads and schools. The local terrace landscapes are internationally renowned and give rise to an increasing tourism. Consequently, in response to the process of China's opening to the external world, and especially the implementation of free-market principles and the development of tourism, the local institutions and ways of living are changing rapidly.

In recent years, agricultural productivism has reached the region and brings new threats to the traditional farming modes and the agricultural landscape (Yang et al., 2017). In the valley, where the altitude allows it, modern improved rice seeds were introduced and the Rice-fish-duck agroecological production system switched to improved rice monoculture relying on a massive use of pesticides and fertilizers (Zhang et al., 2017). Since 2010, in the highlands around the Xinjie town (cf. Table 4.2. below), where the improved modern seeds of the valley are not adapted to the altitude (only adapted up to 1400 m), the government technicians introduced an improved modern seed variety, based on a traditional landrace from the area, called HongYang.

This paper focuses on this area above the 1400 m as it provides a unique situation to analysis the coexistence strategies between the modern HongYang varieties and the landraces. Both the landraces and the modern varieties have phenotypic characteristics that can be recognized by the farmers. Except for some isolated occurrences, these characteristics are relatively stable, as compared to the wild varieties, at least for the period that is relevant for the present study (mutation rates to shift from one variety with given phenotypic characteristics to another take much longer, cf. Zhang et al., 2009). Nevertheless, the modern HongYang varieties are more genetically uniform, as compared to the landraces, which are less homogeneous (Liao et al., 2016).

The seeds of the HongYang variety are promoted by government technicians, because of their higher yields. They were developed by the Yunnan Academy of Agricultural Sciences from seeds selected from their ex-situ seed bank of local landraces, based on agronomic criteria. The seeds are offered for free to the farmers who wish to experiment with the seeds during the first 3 years and then the farmer has to pay for it. In addition, the government offers to the farmers in the first year a guaranteed selling opportunity. In such case, the HongYang rice produced by the farmers is purchased at the price of 6 Yuan/T by state controlled firms, which sell it in towns as typical Yuanyang terrace rice. HongYang rice is the only rice produced upstream the Yuanyang traditional rice terraces that is sold in the neighbouring towns. Moreover, the town inhabitants prefer the taste of the HongYang rice to the taste of the traditional varieties, as it is more neutral as compared to the more pronounced strong taste of the traditional rice.

The seed distribution is organized by government technicians from the prefecture, which are well-known and trusted by the farmers. These technicians contact the head of the village, organize on farm visits to interested farmers and organize the seed distribution to the farmers who have decided to participate. There is no formal contracting and farmers can abandon the program whenever they wish and even just keep the seeds provided by the technicians for their own consumption. The technicians just keep a registry so that they can ask to farmers to pay for the seeds after three years of participation. After the three years, there is no special support plan, but the general support to infrastructure development and access to the markets in the nearby towns continues to supporting the selling of the HongYang rice.

4. Methodology and data collection

To analyse various levels of coexistence between the socio-technical systems, the research team collected data in the upland rice terraces where the government is supporting the cultivation of the HongYang rice. Field visits were organized in villages around Xinjie town during the crop year 2015–2016, two years after the introduction of the seed distribution program in those villages. With the view to have a sufficient diversity in farmer types, a gradient of different villages was selected: three villages that cultivated in majority landraces, four that cultivated in majority modern rice varieties and two villages in between (cf. details in Table 4.1 and 4.2. below).

The data collection combined quantitative and qualitative surveys, which were all conducted through on site interviews. The quantitative survey was conducted through a questionnaire with both open and closed questions. We interviewed 174 farmers with the quantitative survey tool in the nine villages, during field visits in September 2015 and January 2016. In each of the villages, a representative sample of farmers was interviewed, coming from different parts of the village and with different farm sizes.

During the same two field visits, we also conducted 32 qualitative in depth interviews, with the view to collect village level information, gain a better understanding of the farmers' context and to cross-check the consistency of the typology of the various villages (cf. Table 4.1. below). The following persons were interviewed: the 9 heads of the village, 9 farmers, 6 government technicians, 4 researchers working in the area and 4 shamans. These 9 farmers and 9 heads of the village were administered both the quantitative and the qualitative survey during the same field visit.

Finally, a first overview of the results was presented in four focus group meetings that were held in September 2016 (two focus groups meeting with the farmers in two of the villages, one focus group meeting with the group of government technicians that work in the Prefecture and one focus group meeting with agronomic and anthropological researchers from the Yunnan Agricultural University).

The questions of the quantitative survey focused on the various

Table 4.1
Type of farmer groups interviewed in the 9 villages, grouped according to the seed production system.

	#Interviews	Villages with dominance of traditional production systems			Villages with a mix of production systems		Villages with dominance of HongYang modern variety production system			
		V1	V2	V3	V4	V5	V6	V7	V8	V9
No landraces (=100% modern HongYang variety)	55		3	1	3	6	9	16	11	6
1–20% landraces (=80–100% modern HongYang variety)	2	1							1	
20–40% landraces	14		2		2	3	1		1	5
40–60% landraces	14		6		5	3				
60–80% landraces	2					2				
100% landraces	87	17	13	19	11	14	1	3	6	3
Total number of farmers interviewed	174	18	24	20	21	28	11	19	19	14

features of the socio-technical system that were relevant for the analysis of the traditional seed exchange system and the modern variety system (cf. Fig. 3.1 and questionnaire in Annex 1). The 32 qualitative in depth interviews were conducted through an interview outline based on semi-directive questions. The focus group meetings were also based on a presentation of the analysis of the results of the field visits.

Data from the structured survey was analysed through stata 15.1. The analysis of the qualitative interviews was done through regular coding techniques and pattern matching (Dumez, 2016; Miles and Huberman, 2003). We used data triangulation with the literature and the validation via four focus groups of participants to reinforce the reliability of the results. Finally, for all the field contacts we used local translators and cross-checked the translations with a member of the local university and the government technicians.

The statistical regressions of the quantitative survey were computed in three steps: (1) correlation tables were computed for all the individual variables of survey, against the dependent variables (landraces on the plots: 100%; 60–80%; 40–60%; 20–40%;1–20%; 0%); only the variables that showed significant correlations at the 5% level were kept for the next step; (2) probit regressions were conducted with a combination of these variables and the most significant multi-variable probit models kept for subsequent analysis (3) regressions that failed standard collinearity test/wald test were eliminated from the remaining models, based on the following formula:

- Possible collinearity between variables in the multi-variable probit regression was tested through computing the Variation Inflation Factor (VIF) and double checking with the covariance matrix of the error coefficients (stata command: vce, corr). Regressions with possible collinearity problems (VIF > 4) were not considered for the analysis.
- For the multi-variable probit regressions with the same independent variables (cf. Table 4.9. below), we conducted multinomial probit regression with the 3 models (stata command mprobit), to check the validity and to compute the Wald chi-square test for checking the independency of the three models. We only kept the model with associated p value of the test statistic < 0.0001. Below we give the value of the Wald test of the multinomial model, but we present the values of the three multi-variable probit regressions separately, as this gives a higher significance levels for the individual variables.

5. Results and analysis

The analysis of the results is organized as follows. Section 5.1. presents the distribution of the socio-technical systems in the study area. Section 5.2.compares the main drives of choice between these

Table 4.2
Distinctive features of the 9 villages. Xinjie is the main city agglomeration in the neighbourhood, where the farmers can have access to the government technicians, public market and shops for chemicals (Xinjie: Province of Yunnan, China, GPS: 23°09′18.3″N 102°44′52.9″E., average height 1600 m). The classification of the villages in 3 groups is based on the focus group discussion with government technicians and is valid for the 2015 situation. All heights of villages are approximate. Average annual rainfall in the prefecture of study is 1340 mm, 80% of which occurs from May to October and the average temperature is 14 °C (cf. Yuan et al., 2014).

Code	Name of the village	Distinctive features (corresponding to situation in Sept 2015–Sept 2016)
Villages with dominance of traditional production systems		
V1	Huangcaolin, 24 km from Xinjie, 1830 m	Village remains very traditional and is far from the city. Relatively one of the most isolated of the sample. Almost all villagers belong to the same family. Shamanic culture and very strong animist religion (many stelae, altars…). Mass cults are regularly performed (to honour nature for the harvest …)
V2	Turguozhai, 7 km from Xinjie, 1740 m	Attracts a lot of tourism, a bit like Qing kou but less big. Village in altitude. The chief says that one does not make more HongYang because according to him the geography of the village does not allow it (altitude/management of the irrigation).
V3	Luo ma dian, 17 km from Xinjie, 1900 m	Very traditional village (not much infrastructure or new constructions) and difficult to access. The village nevertheless benefits from electrification by solar energy.
Intermediary village (overall mix of the two production systems in the village)		
V4	Qing kou, 9 km from Xinjie, 1700 m	Village with a lot of tourism. One of the most modernized villages but the population pays attention to the typicality and traditions to attract the tourists
V5	Xiaoshuijing, 6 km from Xinjie, 1860 m	More and more farmers are using HongYang. Some farmers use traditional straw for roofs of houses.
Villages with dominance of HongYang modern variety rice production system		
V6	A Hua Zhai, 1 km from Xinjie, 1600 m	Village has been much modernized in recent years in terms of infrastructure. Very close to the main town.
V7	Xiao Xing Zhai, 4 km from Xinjie, 1690 m	Small village with little farmland, because of lack of water. Very poor population. Village leader promoted HongYang rice in response to poverty.
V8	Da yu tang, 10,5 km from Xinjie, 1880 m	For a long time a very traditional village that went through a fast transition the last years. The village is very steep. The villagers sow the HongYang in the lowlands and the landraces in the highlands. Water is very abundant in this village.
V9	shui bu. long cun, 3 km from Xinjie, 1700 m	Government technicians are very influential in this village. Many farmers say that they do not have enough rice to feed themselves. Active intervention of technicians to try to solve the problem. Some use a lot of pesticides, but the farmers also complain that the pesticides are not effective.

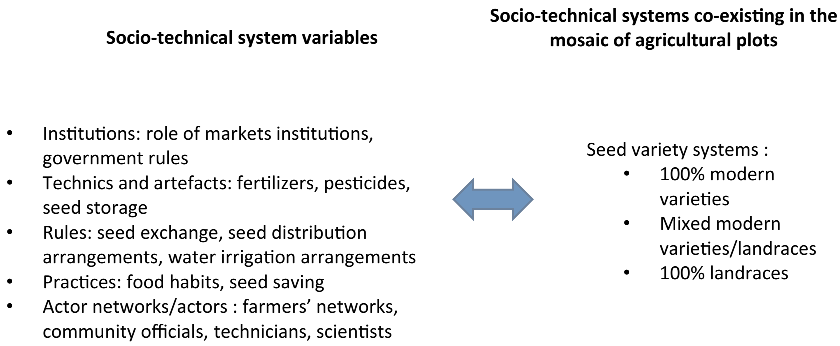

Fig. 3.1. Socio-technical system variables used in the structured surveys.

systems for the individual farmers. Section 5.3. examines which variables of the model presented in Fig. 3.1. best characterize the difference between the socio-technical systems.

5.1. Overview of the socio-technical systems in the study area

As can be seen from Table 4.1, the sample consists of three groups of farmers: farmers in mixed modern varieties/landrace systems (between 20 and 40% and 40–60% of seeds of landraces), farmers that shifted totally to the improved HongYang seed variety (100% modern varieties, all farmers only show 1 variety) and farmers that remained entirely traditional (100% landraces, 90% sowing 1 variety and 10% sowing 2 different landraces or more). Farmers of each type have been interviewed in each of the three types of villages, with the view to control for village specific factors (such as height of the village, infrastructure, etc.). Table 4.2 below illustrates the village specific features.

5.2. The trade-off between market opportunities and biodiversity based disease management

To analyse the main drivers of the choice between the socio-technical systems, this section first presents the change in market opportunities (Table 4.3) and the change in disease impact (Table 4.4) in the various socio-technical systems. Then it presents the survey result on the motivations for change of seeds from one year to another (Table 4.5). To control for change in norms of traditional seed exchange, the results on seed exchange are also briefly discussed (Table 4.6).

5.2.1. Market orientation of crop production

Already in the traditional rice production system, farmers sell some rice outside the community. However, the opportunities for selling on the market increase in the improved rice production system, although not in the same proportion for all the farmers.

5.2.2. Disease impact

The survey results show a clear increase in disease prevalence and disease severity for the farmers that shift to the high-yield rice production system. Although no quantitative assessment was made, disease impact was evaluated by addressing several questions that address this issue from different perspectives. Respondents indicate that disease impact is higher on plots with more seeds of the modern HongYang variety (Table 4.4). These results were cross-checked with similar questions that deal with observed diseases on the plots and a question on the ranking of the main observed changes in disease severity over the last 5 years.

5.2.3. Reason to change seeds

Farmers do change seeds from one year to another, both in the production system based on the modern rice variety and in the production system based on a mosaic of plots with different landraces. However, the decision to change seeds is not based on the same criteria. In the traditional crop management system, regular change in the used crop varieties at individual plot level is the main method used for disease management and yield improvement. In this traditional system the farmer observes the main agronomic features of the rice in his field to orient his decision to change or not his seeds. In the case of the change from landraces to the modern HonYang variety, increasingly new economic market opportunities play a role (such as choice of the rice that can be sold in the city and access of seeds through the market). This trend is illustrated in Table 4.5.

A separate question asked if the farmer observed a decrease in manpower over the last five years. 87% of the respondents indicated that manpower decrease over the last 5 years was not important or weakly important. Even though migration out of the region to the cities is certainly important, this indicates that labour shortage is not a major explanatory factor of shift in production systems in the study area. The absence of a shortage of labourers in the area is also confirmed by a farmer survey from July to August 2015 in the Xinjie town, where rice monoculture is even more important than in the rural villages in the mountain area (Zhang et al., 2017).

5.2.4. Market orientation of seed acquisition

The survey addressed the changes in market orientation in the

Table 4.3
Market orientation of the various categories of farmers (proportion of rice sold, as compared to rice used for direct consumption in the family or in the community).

	Rice used for selling to people outside the community (as a proportion of the produced rice)					
	< 1/4	Around 1/4	Around 1/2	Between 1/2 and nearly all	Nearly all	Total
No landraces (= 100% modern HongYang variety)		33	15		7	55
1–20% landraces (= 80–100% HongYang variety)		1		1		2
20–40% landraces		3	5	6		14
40–60% landraces	1	7	1	5		14
60–80% landraces		1	1			2
100% landraces		87				87
Total	1	132	22	12	7	174

Table 4.4
Disease impact of the various production systems (HongYang, mixed and landraces).

	Total	What is the disease impact on your rice production?				
		No impact	A little impact	Moderate impact	Strong impact	Very strong impact
No landraces (=100% modern HongYang variety)	55	2	11	25	11	6
1–20% Landraces (=80–100% modern HongYang variety)	2	1		1		
20–40% Landraces	14		4	5		5
40–60% Landraces	14	4	6	2	2	
60–80% Landraces	2		1	1		
100% Landraces	87	7	70	8	2	
Total	174	14	92	42	15	11

acquisition of seeds. However, as the seeds of the modern varieties are received for free from the government during the first 3 years, it is difficult to test for this factor. Nevertheless, in spite of the increased market orientation of some farmers, all farmers continue to follow the classical community norms for seed exchange. Indeed, as shown in Table 4.6. both seeds of the landraces and seeds of the modern HongYang variety continue to be exchanged amongst the farmers. In addition, the survey showed that these exchanges remain largely based on non-market mechanisms (reciprocity, community rules, reputation, etc.): farmers never ask monetary compensation when providing seeds to other farmers.

5.3. Comparative analysis of the various socio-technical systems co-existing in the agro-ecological landscape

This section presents the statistical regression to evaluate the importance played by the various socio-economic variables presented in Fig. 3.1, for the choice by individual farmers between the socio-technical systems. To conduct this analysis, this section conducts two comparative analyses:

(1) The first presents a comparison of the farms with 100% modern HongYang variety and farms with 100% landraces. The goal of this first step is to better understand the contrasting features of these socio-technical systems (Section 5.3.1)
(2) The second presents a comparison of these systems with the farmers that adopt mixed landrace/modern variety systems (Section 5.3.2).

5.3.1. Comparison of the agronomic and socio-economic features of the two "pure" socio-technical systems

This model presented in Table 4.7. shows that farms with 100% modern HongYang variety are correlated with the following features.

"Advise of the head of the village in obtaining information about new seeds" is highly significant (at the 1% level), as compared to the three other options the interviewee could select (information on new seeds based on observation or discussion with other farmers, the government technician, or no information received). The qualitative interviews give some additional information on this finding. Indeed, the interviews show that the traditional head of the village plays a role of problem solver. The head of the village does not have a command role or an official mandate, but when farmers have problems or needs they seek for the head. We observed that the farmers that had strongly shifted towards the modern variety socio-technical system no longer select their seeds based on field observation, but by following the advice of the government's agricultural development technicians, whom they can consult on a voluntary basis. If these technicians are not present (which is the situation of most of the cases in the studied villages), the farmers ask the village head for advice, the head then travels to the city to consult the technicians and the market sellers of the new variety.

Table 4.6
Seed exchange practices.

Seed exchange practices		
If a farmer that you know come to you and ask you to provide him seeds do you agree?	No	0
	Yes	174
If it is a stranger do you agree?	No	3
	Yes	171
Even for any seeds?	No	1
	Yes	173

The variable "a moderate impact of disease" is significant at the 1% level, as compared to the other options the interviewee could select (no impact, al little, strong or very strong). This indicates an increase in the presence of diseases. As seen above, in the overall sample around 60% reported "no impact" or "a little impact". Moreover, the variable "very strong impact" was excluded from the regression as it was collinear with the "modern variety" sub-sample: all 11 farms with "very strong" are part of the 100% modern variety sub-sample.

The variable "strong" disease impact is very significant (at the 5% level), as compared to the other options. This is consistent with the overall trend of a high level of diseases on the modern variety farm plots and indicates that there are two sub-groups in the 100% modern varieties sample, respectively with moderate and strong disease impact.

The higher level of selling of the rice on the market is significant at the 5% level. It indicates a comparatively strong market penetration, even though overall farmers still use rice for their own consumption, as shown in the Table 4.3.

The high use of chemicals (significant at the 5% level) indicates a strong shift in the practices as compared to the traditional farming

Table 4.5
Reasons for change in seeds from one year to another in the various production systems.

	% of interviewees of the farmer type that selected the option (multiple answers possible)					
	Decreasing yield production	Economic opportunity	Bad taste of rice	Crop disease	Instability of yield production	I did not change the last five years
No landraces (=100% modern HongYang variety) (55 interviewees)	47	64	38	18	27	
20–40% landraces (14 interviewees)	29	79	29	21	7	
40–60% landraces (13 interviewees)	79	43	43	7	7	
100% landraces (87 interviewees)	57	2	20	45	31	20

Table 4.7
Multi-variable probit regression model of socio-technical system of 100% seeds of the modern HongYang variety.

		Dependent variable:		
		Type of seeds on farm: 100% seeds of the modern HongYang variety		
		Coef.	Std. err.	P > |z|
Independent variables				
How do you get information on the new seeds: advises from head of the village	(+)***	1.89428	0.44425	0.000
Disease impact on production: moderate impact	(+)***	0.96963	0.33841	0.004
Disease impact on production: strong impact	(+)**	1.00734	0.45839	0.028
Rice used for selling: or around 1/2 or between 1/2 and nearly all the rice	(+)**	0.70371	0.35494	0.047
Very often use of chemical products when having crop disease problems	(+)**	0.65874	0.30687	0.032
Organization or individual that provided the seed most used this year: government technician	(+)**	0.72414	0.28338	0.011
Disease severity as moderately important change seen over the last 5 years	(+)*	0.79852	0.40902	0.051

Prob > chi2 = 0.0000.
n = 174(full sample).
VIF (variance inflation factor): mean VIF = 1.61; max value of VIF for individual variables = 1.91.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

systems.

The influence of the government technician is significant at the 5% level, as compared to the other options for seed acquisition which are “farmer of my village”, “farmer outside of my village” or “market”. This is related to the fact that during the first three years of adoption of HongYang varieties, the seeds are provided for free by the government. In some cases the government technicians also provide the chemicals for free, but this is rather exceptional (10% of the cases for modern varieties).

Finally, the option “moderate change in disease severity” is moderately significant (at the 10% level). This is consistent with the comparatively higher disease impact, as most respondents answered “no important change in disease impact” (58% of all respondents).

The probit regression presented in Table 4.8. highlights the features of the socio-technical system based on the adoption of 100% landraces on the farm plots. The variables that are highly significant (at the 1% level) are less selling of rice, few use of chemicals (as compared to the other response options) and the provision of the seeds through the informal farmers' exchange networks. Variables that are very significant (at the 5% level) are “less impact of diseases” and “use of seed selection as the main disease management tool”.

5.3.2. Farmers adopting mixed landrace/modern variety socio-technical systems

The above regressions show the characteristics of the “pure” production systems. Based on the regressions and the analysis of the descriptive data, two set of features can be distinguished:

(1) For 100% modern variety production plots: market oriented use of the crop production (selling) and provision of the seeds by government technicians
(2) For the 100% landraces' plots: subsistence and family use of the rice, and provision of seeds through farmers' seeds exchange

The regression results therefore shows a clear difference between the influential actors that play a role in each of these two production systems, respectively the government technicians for the farmers adopting the modern varieties and the reciprocity networks between farmers for the landraces. As a consequence, on the village level, these two social networks co-exist, but clearly operate separately from each other.

Some farmers do not entirely shift towards the modern variety system, but opt for a mixed landraces/modern variety model. To better understanding the features of the mixed socio-technical system at the individual farmers' level, we constructed regressions with different levels of adoption of the modern varieties and compared it to the 100% landrace systems. The search for the regression models with the most significant results on the variables of the socio-technical system model presented in Fig. 3.1. lead to three clearly distinct groups of farmers that are characterized by different levels of market orientation, use of

Table 4.8
Multi-variable probit regression model of socio-technical system of 100% landraces.*

		Dependent variable:		
		Type of seeds on farm: 100% landraces		
		Coef.	Std. Err.	P > |z|
Independent variables				
Use of rice production for selling (< 1/4 to nearly all on a 5 point Likert scale)	(−)***	−1.87966	0.54743	0.001
Sometimes use of chemical products when having crop disease problems	(+)***	1.47177	0.32832	0.000
Provision of the seeds: farmer of my village	(+)***	1.39185	0.38303	0.000
During the five last years, why did you change seeds: managing crop disease or I did not change seeds	(+)**	0.63054	0.30800	0.041
Disease severity changes over the last 5 years (5 point likert scale: not important to very important)	(−)**,*	−0.42557	0.19124	0.026

Prob > chi2 = 0.0000.
n = 174(full sample).
VIF (variance inflation factor): mean VIF = 2.82; max value of VIF for individual variables = 3.27.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

Table 4.9
Multi-variable probit models for the mixed (landrace/modern variety) systems (the detailed regression coefficients are given in the table in Annex 1).

	Dependent variable: type of seeds on farm		
	0–40% Landraces (71 out of 174)	40–80% Landraces (16 out of 174)	100% Landraces (87 out of 174)
Independent variables			
Info on new seeds: head of the village	(+)***	perfect pred.	(−)**
During the five last years, why did you change seeds: economic opportunity	(+)***	(+)**	(−)***
Disease severity changes over the last 5 years (5 point Likert scale: not important to very important)	(+)**	(−)**	(−)*
During the five last years, why did you change seeds: managing crop disease or I did not change seeds	(−)**	(−)***	(+)***
During the five last years, why did you change seeds: decreasing yield	(−), ns	(+)*	(−), ns
Disease impact on production: no impact or a little impact	(−)**	(+), ns	(+)**

ns: non significant.
* Significant at 10% level.
** Significant at 5% level.
*** Significant at 1% level.

chemicals and influential actors (cf. results in Table 4.9):

- Farmers with 0–40% landraces (71 out of 174): farmers that opt for modern varieties primarily for the economic opportunities (rice with a taste that can be more easily sold on the city market), in spite of increase of disease, higher need of chemicals for disease management of the modern varieties, and absence of a concern for decreasing yields
- Farmers with 40–80% landraces (16 out of 174): farmers that opt for modern varieties for a mix of economic opportunities and yield concerns, but which do not see a major increase in diseases
- Farmers with 100% landraces (87 out of 174): farmers that do not opt for modern varieties

These 3 types of farmers are present in most of the villages of the sample (cf. Table 4.1). As the villages are very diverse, this indicates that the difference between these groups are not primarily the agricultural or geographic conditions, but the social networks to which the farmers belong and the individual motivations and economic situation of the farmer.

The variable “head of the village” in Table 4.9. shows a perfect prediction for the 40–80% landrace systems, meaning that for all the farmers in this category, the head of the village provided them the information on the new seeds. This is in clear contrast with the 100% landrace system analysed in Table 4.8, where the main information on the new seeds comes from other farmers in the village. As also learned from the qualitative interviews, the head of the village plays the role of the intermediary between the farmer and the government technician that provides the new seeds.

In general, for the farmers of the 40–80% group, economic opportunities are less mentioned as a strong reason, as compared to the 0–40% group, but play nevertheless a significant role.

For the farmers that shift very strongly or totally to modern varieties (0–40% landraces), disease severity strongly increases. In contrast, in the group of 40–80% landraces there is no observation of increase in disease severity. The latter was confirmed by running a probit model with the same variables as Table 4.9., but without the “Increase disease severity” variable. In the latter model, the variable “Little disease impact” becomes significant at 5% level, with positive sign. These findings on the group of 40–80% landraces indicate that disease prevalence is very low when a substantial amount of landraces is maintained on the individual farmers' plot, even if the farmer adopt a substantial amount of modern varieties (most of the farmers in this group have between 40% and 60% of landraces, so between 40% and 60% of modern varieties).

Other factors have a comparatively strong correlation within the 40–80% group. First, the fact that the “change for managing crop disease” variable is negatively correlated shows that the traditional disease management mechanism (changing the seeds of the landraces to manage the diseases) has already become less important for these farmers.

Further, complementary analysis also shows that around 40% of the farmers in this group indicate manpower decrease as an important to very important change over the last 5 years, compared to an average of 10% of the respondents over the entire sample. This result provides further evidence of important social changes in this farmer group. In addition, 50% of the farmers in this group have 3 to 5 times a year or 1 to 2 times a month a contact with a technical agent of the government to discuss disease management, compared to the average over the total sample which is around 20% (all others have less frequent contacts). So specific influential actors, such as the government technician or the head of the village, and changing norms and social conditions probably play an important role in the intermediary group of farmers that are testing the new seeds.

6. Discussion

Overall, the analysis of this case of coexistence in the Yunnan rice terraces shows that the major features of the socio-technical systems that play a role in the choices made by the individual farmers are not the agronomic conditions, although they certainly play a role, but economic and social features. These results were confirmed by the participants in the focus groups, which in addition to the confirmation, also underlined the importance of addressing the further development of market opportunities for the farmers of the region.

First, adoption of the modern HongYang variety is strongly determined by the new economic opportunities offered by increased market accessibility for this variety. In particular, farmers' decisions reflect an adaptation to the possibility to sell rice in the nearby town (between 1 and 24 km from the mountain villages) and the high demand of urban inhabitants for the rice produced from modern varieties. The urban inhabitants are not used to the taste of the rice from the landraces and do not buy this rice. Other features play a much less important role. The survey results show that all seeds (both landraces and HongYang varieties) continue to freely be exchanged amongst farmers in the village, so availability of the seeds is not a major driver or barrier. In addition, using results from similar areas in the Yunnan, it is likely that the gain in yields of the modern varieties, compared to the average 4–6 t/ha of the landraces used in the intensive terrace system, is not substantial (cf. for instance He et al., 2011; Fullen et al., 2017).

A second major outcome of the analysis is that the decision to shift to the market oriented production systems by individual farmers is strongly influenced by social factors, in addition to the economic ones. Major social factors that play a role in the shift to modern varieties highlighted by the analysis are changes in the norms of disease management (decrease in use of farmers' saved seed exchanges for crop disease management), the presence of influential actors (government technicians/head of the village), and the impact of eating habits of the urban inhabitants, mainly their preference for a certain taste of the rice. On the other hand, as shown directly through the survey results, traditional systems of exchange still play a strong role in the more traditional villages, in particular through information exchange with other farmers, reciprocity networks for seed distribution and cultural preferences for traditional rice (cf. for similar results, van Niekerk and Wynberg, 2017).

As highlighted in Section 2, current approaches of coexistence between market and non-market coordination mechanisms show three major modes of coexistence: stratification (serving different consumers/users), competition (for the same consumers/users, potentially leading to the disappearance of one of the systems) and mutually supporting influence (based on common interests/synergies between the two systems).

From a socio-technical perspective, the model that best fits the data is a model of stratification. Indeed, the modern variety system and the landrace system each address different user/consumer demands and are based on a different set of socio-economic institutions and practices, as analysed in Section 5.3.1. Such stratification is in line with the findings of the seminal research by Stephen Brush and his colleagues on the coexistence between maize landraces and modern maize varieties in Central Mexico (Perales et al., 2003). In their study, coexistence was found in the mid-elevations in Central Mexico. In this area, landrace cultivation is sustained in a mixed modern variety/landrace system because of good agronomic performance and a set of end-use qualities such as taste and use in cultural practices. Similar situations of coexistence have been identified for Millet and Sorghum in rural areas situated close to grain market in Mali (Smale et al., 2010), for potato in the Cochabamba province of Bolivia (Almekinders et al., 2010) and for rice in Nepal, both in the planes and the hills (Pant et al., 2011), amongst others. Interestingly, these studies also highlight taste of the food products as an important trait that is valued by the farmers that are growing seeds of landraces (cf. Ibid.).

The research by Melinda Smale and her colleagues in Mali shows that the main driver for the introduction of the modern varieties are markets and extension services, which is also in line with our results. Further, it is interesting to notice that in the mixed landrace/modern variety system in Mali, landrace seeds also continue to be provided freely in farmer exchange networks, as this is a matter of social custom and social recognition of the farmer by his community members (Smale et al., 2010). The clear distinction between the social recognition networks for the landraces and the formal markets for the modern varieties further supports the stratification model (Sperling and Longley, 2002).

The stratification model found in this study differs from the more well-known model of competition and disappearance of landraces, in situations of increased market accessibility and changing consumer/user demands (Pascual and Perrings, 2007). However, as also highlighted in other studies, better market integration does not necessarily pose a threat to the use of landraces. On the one hand, more vulnerable farmer situations and exposure to risk of crop failure limits the adoption of modern varieties in mixed modern/landrace systems (Smale et al., 2012; Wale and Yalew, 2007; Katungi et al., 2011). On the other hand, farmers in more accessible areas are prone to move towards the adoption of modern varieties in the mixed systems, without necessarily negatively impacting the intra-specific biodiversity of the area (Salazar and Winters, 2012).

Finally, research on coexistence also highlights a complementary pathway that was not developed by the farmers at the time of the study visit, which is the development of consumer labels for landraces. Other studies have highlighted the possibility of supporting stratification, based on the willingness of consumers to pay a price premium for landraces from traditional and/or more environmentally sustainable production systems (Krishna and Pascual, 2009; Garcia-Yi, 2014). The exploration of this pathway in the area is actively considered by some farmers, as evidenced by the focus group discussions.

The research also hints to some possibilities of mutual synergies, beyond mere stratification. The review of the literature on agro-ecological systems above already shows the potential for mutually supporting influence amongst the landrace and modern variety production system, in particular through pest and weed reduction resulting from more diversified production system (cf. Zhu et al., 2000, 2003; Zhang et al., 2011). From an agro-ecological perspective, this mutually supporting influence is confirmed by the results of this study. Indeed, in the mixed landrace/modern variety systems, the presence of landraces tempers the appearance of the high level of diseases associated with the introduction of the modern varieties. However, other agro-ecological variables also might play a role, and the sample size of farmers in the group of 40–80% landraces is too small to determine what other variables determine this decrease in disease prevalence, in addition to the presence of genetic diversity on the individual farmers' plots. In particular, a more systematic analysis would be needed at the regional landscape level to be able to distinguish between the effects at individual farmers' plot level and the aggregated effects of the diversity at the landscape level (Hannachi and Dedeurwaerdere, forthcoming).

Some additional caveats need to be considered in the interpretation of these results. First, the context of each of the 9 villages has an important impact on the performance of the two distinct socio-technical systems. The present study uses a sample representative of a broad variety of bio-physical features (such as height, water access and soil quality) and socio-economic features (such as variation in distance from the city, importance of shamanic cultures versus more modern villages and infrastructure). Nevertheless, a larger sample would be needed to analyse the precise impact of these contextual variables.

A second caveat applies to the available information on the performance of the various farming systems. Most farmers in the Yunnan highlights shift totally to a new production system (100% modern varieties) or totally maintain the traditional production system (100% landraces). Therefore most information is available on these pure socio-technical systems, which we compared in Table 4.7 and Table 4.8. More information is needed on the many possible production choices for the mixed socio-technical system. For this, the experimentation that is ongoing in some of the villages is interesting, but additional sites and forms of experimentation are required to constitute a reliable information base that can provide guidance according to various contextual circumstances and coexistence scenarios.

Third, this paper did not analyse the market potential of the landraces. Indeed, before the experiment introduced by the government with the HonYang varieties, and before the relatively recent improvement in road infrastructure in the region, farmers did not consider to sell their crop harvest on the market in the town. With the opening-up of the new marketing channels for the HongYang rice, and the concomitant change in social norms, farmers might consider to start selling products from the landrace plots in the town if a demand for traditional rice with stronger, less neutral, taste can be found.

Fourth, seen the timing of the interviews, two year after the introduction of the program in the villages, this study was not able to analyse the effects of the government program in the long run. Further follow-up research in the area might be helpful to understand the impact of the socio-economic drivers in the long run, after this period of rapid transformation.

7. Conclusion

Research on the bio-physical features of genetically rich crop production systems shows that in theory mixed landrace/modern variety farming systems can provide interesting benefits to the farmers. In particular, the introduction of modern varieties does not necessarily seem to put traditional biodiversity based disease management systems into danger. The condition for this balance is that the mosaic of diverse varieties is sufficiently large to continue to function as a buffer against diseases. Through an in depth case study of genetically diverse rice production systems in the Yunnan highlands, the paper shows that production systems with modern varieties and landraces can co-exist.

The analysis shows that the major driver of choices for one of these socio-technical systems are not the agronomic conditions, although these certainly play a role, but the new market opportunities generated by the selling of rice from modern varieties to urban inhabitants and the actor networks surrounding the farmers. In sum, all three systems analysed in this paper (the pure landrace, the pure modern varieties and the mixed) are characterized by a distinct set of socio-technical features. Room for improvement however also exists in these various systems. In particular, for the production systems based on the landraces, market opportunities are very low and room for improvement exists, for instance through systems of labelling and/or through the selection of landraces that also reflect the food taste preferences of the urban inhabitants. On the other hand, the high level of use of chemicals in the production system with modern varieties is a major concern for the sustainability of the complex agro-ecological landscapes of the Yunnan highlands. Increasing the genetic diversity on the plots, such as in the mixed systems, and removal of adverse incentives, might contribute to reaching a better balance.

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Annex 1

Detailed regression results for Table 4.9: Multi-variable probit models for the mixed (landrace/modern variety) systems.

Variable name	Variable definition	Dependent variable: Type of seeds on farm: 0–40% landraces (71 out of 174)	Coef.	Std. Err.	P > |z|
Little dis imp	Disease impact on production: no impact or a little impact	(−)**	−0.6105	0.28005	0.029
Increase dis sev	Disease severity changes over the last 5 years (5 point Likert scale: not important to very important)	(+)**	1.84157	0.51545	0.000
Motiv_Econ opp	During the five last years, why did you change seeds: economic opportunity	(+)***	0.52325	0.16572	0.002
Motiv_Decr yield	During the five last years, why did you change seeds: decreasing yield	(−), ns	−0.70563	0.32487	0.030
Motiv_Manage dis	During the five last years, why did you change seeds: managing crop disease or I did not change seeds	(−)**	1.19023	0.32306	0.000
Head of vill	Info on new seeds: head of the village	(+)***	−0.02501	0.27951	0.929

	Dependent variables: Type of seeds on farm: 40–80% landraces (16 out of 174)	Coef.	Std. Err.	P > |z|	Type of seeds on farm: 100% landraces (87 out of 174)	Coef.	Std. Err.	P > |z|
Little dis imp	(+), ns	0.414	0.5292	0.434	(+)**	1.40009	0.32179	0.000
Increase dis sev	(−)**	−0.63454	0.27178	0.020	(−)*	−1.25062	0.5066	0.014
Motiv_Econ opp	(+)**	1.21502	0.50801	0.017	(−)***	−0.32715	0.1943	0.092
Motiv_Decr yield	(+)*	0.72084	0.37757	0.056	(−), ns	0.71294	0.35962	0.047
Motiv_Manage dis	(−)***	−1.50092	0.51096	0.003	(+)***	−0.3517	0.30284	0.245
Head of vill	perfect pred.				(−)**	−2.25183	0.47104	0.000

For each of the three regressions:

Prob > chi2 = 0.0000
*Significant at 10% level; ** at 5% level, *** at 1% level, ns: non significant
n = 174 (full sample)
Average value of VIF (variation inflation factor) < 2.16; max VIF of individual variables < 2.83
Variable “Head of Village” deleted in regression 40–80% landraces (perfect prediction)
Wald test of the multinomial regression with 5 independent variables (without “Head of village”): Wald chi2(10) = 61.04; Prob > chi2 = 0.0000

Annex 2. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolecon.2019.01.026.

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