

## RESEARCH ARTICLE



# Quantifying unintended effects of an agroecological research project on farmers' practices and social network in Papua New Guinea

Mirjam Hazenbosch<sup>1</sup> | Shen Sui<sup>2</sup> | Brus Isua<sup>2</sup> | Emilie Beauchamp<sup>3</sup> | Alfred Kik<sup>2,4</sup> | Grace Luke<sup>2</sup> | Petr Matouš<sup>5</sup> | Rebecca J. Morris<sup>1,6</sup> | Jason Paliau<sup>2</sup> | E. J. Milner-Gulland<sup>1</sup>

<sup>1</sup>Department of Zoology, University of Oxford, Oxford, UK; <sup>2</sup>The New Guinea Binatang Research Centre, Madang, Papua New Guinea; <sup>3</sup>International Institute for Environment and Development, London, UK; <sup>4</sup>Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic; <sup>5</sup>Faculty of Engineering and Information Technologies, University of Sydney, Sydney, New South Wales, Australia and <sup>6</sup>School of Biological Sciences, University of Southampton, Southampton, UK

## Correspondence

Mirjam Hazenbosch

Email: [mirjam.hazenbosch@gmail.com](mailto:mirjam.hazenbosch@gmail.com)

## Funding information

Biotechnology and Biological Sciences Research Council, Grant/Award Number: BB/M011224/1

Handling Editor: Samantha Grover

## Abstract

1. Agroecological researchers and advocates often make assumptions about the social impact and dissemination of their work: researchers may assume that their work has impact through postresearch dissemination, while advocates may assume that new agroecological practices can be effectively spread through existing social networks.
2. Here, we test these assumptions by quantifying the effects of an agroecological research project on farming practices and the social network in a village community in Papua New Guinea. The project aimed to test the effect of applying banana peel compost, chicken manure and NPK fertiliser on sweet potato yields. Local farmers were involved in the research as project garden owners or research assistants. Using stochastic actor-oriented modelling, we tracked changes in farming practices and the social network.
3. Over the course of the research project, more people started to use food waste on their farms, while animal manure and NPK fertiliser were not frequently adopted. Farmers also took up practices that were not directly researched, such as mulching and planting the specific variety of sweet potato that was used in the project. This suggests that local farmers created meaning from the project, despite the researchers not intending to give advice until the end of the project.
4. The research project also affected the community's social network. Research assistants became more often sought-after for advice, while knowledge about the project did not flow far from those directly involved. These results indicate that who gets involved in a project may have social consequences, and show

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2022 The Authors. *People and Nature* published by John Wiley & Sons Ltd on behalf of British Ecological Society.

the importance of understanding existing social networks before they are relied upon for spreading farming practices.

5. Overall, this work challenges often-held assumptions about the social impact and dissemination of agroecological research, provides insights into the types of agricultural innovations more likely to be accepted among farmers, and explores how new practices may most effectively be promoted within a community.

#### KEYWORDS

behaviour change, fertiliser, knowledge exchange, science-policy gap, social network analysis, stochastic actor-oriented modelling, sweet potato, swidden agriculture

## 1 | INTRODUCTION

Agroecology aims to solve challenges in agricultural production. To achieve this, different approaches are taken, with 'agroecology' not only being an agricultural practice but also a scientific discipline and a social movement (Wezel et al., 2009). Agroecological researchers focus on investigating factors affecting agricultural production, while agroecological advocates use agroecology to drive forward a political agenda on sustainable agriculture, rural development and environmentalism (Wezel et al., 2009).

Agroecological researchers often work in collaboration with farming communities and spend a significant amount of time 'in the field' to collect their data. It is often assumed by these researchers that their work may impact farmers' practices, but only at the end of a project (Bertuol-Garcia et al., 2018). Much of the literature on how to bridge the so-called science-policy gap also stresses the importance of communication, dissemination and implementation once the research is done (Toomey, 2016). However, some have begun to question the supposedly linear relationship between science and society, arguing that it does not adequately recognise the complex interactions that exist in the spaces and places in which research takes place, especially when the research is field-based (van Kerkhoff & Lebel, 2015). For example, Hakkarainen et al. (2019) described how local fishermen thought of ways of making their fishing business more profitable, based on information collected by a researcher, despite the researcher not intending to give advice about this. Ideas of linear knowledge transfer are increasingly replaced by more complex understanding of knowledge exchange in which research is embedded in society and has impact not only upon its completion but also during the research process (Toomey et al., 2017).

There are very few studies that quantify the real-time effects of an agroecological research project on the community in which it takes place (Toomey, 2016). It is, however, important to better understand the impacts of the scientific process, as it can affect the lives of local people (Beaman & Dillon, 2018; Brittain et al., 2020), influence the acceptance of research results by local actors (Toomey, 2016), and affect the long-term acceptance of research activities in a community (West, 2006). Positive or negative effects of a research project can have far-reaching consequences for local society and the environment, and thus need to be understood (Shackleton et al., 2009).

This is especially true when subsistence resource users are involved, because they make important decisions which affect the dynamics of their natural resources and have consequences for their own food security and biodiversity conservation (Shackleton et al., 2009).

Contrary to researchers, agroecological advocates who promote the use of agroecological practices by farmers, aim to have impact from the onset of a project. Usually agroecological extension officers target specific farmers within a community and provide them with training on new agroecological practices (Beaman & Dillon, 2018). These farmers are then expected to influence their wider community (Genius et al., 2014). Whether this works, and which farmers could best be targeted, depends on the information-sharing relationships among farmers (de Lange et al., 2019). It is increasingly becoming clear that top-down linear models of knowledge transfer in which information flows directly from extension officers to farmers often do not represent reality accurately. Instead, nonlinear models in which farmers' interpersonal connections, learning style and decision-making processes are taken into account are being developed to more accurately represent and understand how information on agroecology spreads (de Lange et al., 2019; Matous et al., 2013a).

Social network analysis has emerged as a suitable tool to investigate the structures and properties of an information-sharing network (Groce et al., 2018). Few longitudinal, empirical studies directly address how social networks affect natural resource management in rural settings of the Global South (Groce et al., 2018; Isaac et al., 2021). This is likely to be due to the difficulty of obtaining appropriate data in such settings, and potentially lack of access to the complex modelling tools that such data often require (Matous & Todo, 2015). It is crucial to have a solid understanding of social networks among smallholder farmers as it helps agroecological extension officers to know how social networks can be relied upon for effectively spreading information and how changing farming practices may be achieved (Groce et al., 2018; Matous & Todo, 2015). It is also important to find out how agroecological researchers and advocates may be affecting local networks and the processes that take place within them as a side effect of their activities, so that potential unintended negative effects can be avoided (Isaac et al., 2021).

Here, we report on the effects of an agroecological research project on farming practices and the social network in a village community in Papua New Guinea (PNG). The research project aimed to

investigate whether the use of fertilisers could increase the yields of swidden farmers (Hazenbosch et al., 2021). To achieve this, the research team established experimental plots on the fields of swidden farmers, applied locally available fertilisers, and tracked soil quality and crop yields of sweet potato for 12 months. Depending on which fertiliser yielded the best results at the end of the experimental trial, the research team intended to inform local farming practices after the work had finished. However, we observed that even while the research took place, farming practices and information-sharing practices among local farmers were changing. This spontaneous diffusion was unexpected and not part of the original research design and hypotheses. We decided to track and quantify this spontaneous diffusion to better understand how agroecological research can actively shape individuals' behaviours and a community's social network.

In this study, therefore, we investigate contemporaneous effects of our study on farming practices. In order to analyse these effects, we conceptualised the setting as a network system, and tracked and quantified the joint evolution of farming practices and the social network. We estimated the underlying processes through simulations using stochastic actor-oriented modelling. The results challenge often-held assumptions by agroecological researchers and advocates. They also help explore what type of agricultural innovations are likely to be accepted among farmers in this setting, and how practices may be most effectively promoted within a community.

## 2 | MATERIALS AND METHODS

### 2.1 | Context

In February 2018, as a team of Papua New Guinean and international researchers, we entered Ohu village (S 05°13.081', E 145°40.735') to conduct scoping research on soil quality and crop yields. Ohu has hosted various research projects since 1995 and has a long-standing collaboration with The New Guinea Binatang Research Centre (NGBRC), a local nonprofit organisation committed to conducting biological research and conservation. NGBRC's research projects have been a significant source of income and opportunity for training in Ohu, and several members of Ohu community have gone on to become full-time staff with NGBRC. Most research in Ohu done so far focused on studying insects, plants, birds, bats and fungi present in the local forests (Weiblen & Moe, 2016). We were one of the first research projects in Ohu to focus on swidden agriculture specifically. To our knowledge, no other agriculture-related projects were conducted in Ohu from 2018 to 2019.

In August 2018, the research team was granted permission from local leaders to set up experimental gardens. Ten gardens were established on the land of local farmers. Some farmers were involved in the research project as project garden owners or research assistants. Project garden owners were actively involved in monitoring of the experimental gardens, whereas research assistants contributed

to preparing and harvesting the gardens. The local assistants came from four different clans, out of a total of 11 clans which make up Ohu village. In the experimental gardens, the effect of different soil enhancement techniques, including applying banana peel compost, chicken manure and commercial NPK fertiliser on soil quality and crop yield were tested. Traditionally, farmers in Ohu do not use these fertilisers in their food gardens (Hazenbosch et al., 2021). Sweet potato (*Ipomoea batatas*) was chosen as the focal crop as it is a staple in PNG (Bourke & Harwood, 2009). We asked a local farmer to select a suitable variety of sweet potato, which the team could grow in the experimental gardens. The farmer selected one variety locally called 'wan mun kaukau'. It later turned out that the farmer did not have much experience growing this specific variety, so was keen for us to try it. The experimental gardens were actively used for research throughout the following year.

### 2.2 | Survey

To track changes in farming practices and the community's social network, we administered two waves of interviews, one at the beginning of the research project and one at the end. The first wave was conducted in November and December 2018, three months after setting up the experimental gardens but before the first harvest of the experimental gardens. The first wave of interviews cannot be considered a true preproject baseline. But given that the interviews took place before the results of the first harvest were collected, we assume that people were not changing their farming practices yet as a result of our findings and that the research project had had a minimal influence on the social network thus far. Even if there had already been some effects, we would be underestimating rather than overestimating the overall impact of the research project on local farming practices and the social network. The second wave of interviews was conducted after the final harvest of the experimental gardens in July and August 2019 (a year after setting up the experimental gardens), with three final interviews being conducted in October 2019 due to unavailability of the participants in earlier months.

The team collected data from 63 people across the four clans in Ohu that were involved in the research project (Table 1), which represents ~80% of the household heads in these clans. We interviewed both the male and female head of each household, because in PNG men and women farm together on shared fields and are thus both agricultural decision-makers (Pamphilon & Mikhailovich, 2017). The four clans live on geographically neighbouring land. We had to exclude interview data from six farmers, either because during the second survey they were no longer present in the village (two people) or they did not want to take part in the second interview (four people). Free prior-informed consent was given by all participants before the start of the interviews. The interview protocol was approved by the University of Oxford's Research Ethics Committee under permit number R58337/RE002.

Interviews were done face-to-face in Tok Pisin (PNG's lingua franca) using fixed-form data sheets by our research team from

**TABLE 1** Description of the sample. Total sample size consisted of 57 participants

	Non-participants	Project garden owners	Research assistants
Number of people overall	33	10	14
Age (mean in years)	42	40	38
Gender (no. of ♀)	17	6	3
Clan 1 (no. of people)	7	4	0
Clan 2 (no. of people)	16	1	3
Clan 3 (no. of people)	9	5	10
Clan 4 (no. of people)	1	0	1

NGBRC and the first author (Appendix, Section 1). In the first part, we collected demographic information, such as age, gender, clan and main livelihood of the interviewee. We also recorded Global Positioning System coordinates of the interviewee's house so we could calculate the shortest distance in metres between houses of respondents. People in Olu can walk from one house to the next in more or less a straight line, so we did not apply any transformations when calculating distances between two points.

Next, we recorded the interviewee's farming practices. Some of the farming practices we asked about, including the use of food waste, animal manure and NPK fertiliser, were directly associated to our research project. Food waste corresponded to our banana peel compost treatment, animal manure to our chicken manure treatment and NPK fertiliser to our NPK fertiliser treatment. Others, including the use of grass, leaves or plant residues besides food waste (henceforth called mulch), were related to our research project, but not specifically tested in the experimental gardens. We asked about both directly associated and related farming practices to better understand the potential unintended effects of the research project on farming practices.

In the third part of the survey, we collected data on farmers' most important information sources regarding their food gardens. Specifically, the English translation of the network prompt was: 'Now we need you to think about people in the village you have talked to most often about farming over the last year. Could you give us the names of up to five people who you regularly talk to about your food gardens?'. The elicited networks were preserved in their directed form. This allowed us to distinguish between information seekers, conceptualised as nominating many others (i.e. actors with a high out-degree in network science terminology), from popular advisors, conceptualised as often being nominated by others (i.e. actors with a high in-degree). Network analysis requires setting a meaningful boundary. In this study the boundary of the network is the clans that were involved in the research project. We only considered links within the selected boundary and discarded outgoing links, as is usually done within network analyses.

In the second interview wave, there was a fourth part to the interview in which we asked participants about why or why not they were using a certain farming practice, whether they had changed

the variety of sweet potato that they were planting, and whether and what they had learned from the experimental research project (Table 2).

## 2.3 | Statistical analyses

The main aim of the analyses was to determine how the research project affected farmers' behaviour and social network. These can be interconnected, though, with people who exchange information being more likely to display similar behaviour (i.e. social influence), and people behaving similarly having a higher chance of forming friendships (i.e. social selection) (Snijders et al., 2010). To analyse the joint evolution of farmers' behaviour and social network, we conducted stochastic actor-oriented modelling (SAOM) (Snijders et al., 2010) in R version 4.0 (R Core Team, 2020). For a full explanation of SAOM, see Appendix, Section 2.

In short, a SAOM is based on the assumption that the network evolves as a stochastic process that is driven by its actors, in our case the farmers whom we interviewed. A SAOM models the change between two observed periods, such as between a first and second wave of interview data. Between these two observation moments, actors receive chances to change the ties in their network in a random order. Actors can also choose to increase, decrease or maintain their level of behaviour. SAOMs allow the specification of 'effects' which represent ways in which network structures and covariates affect the network or behaviour. Examples of effects include the 'reciprocity effect', which represents the tendency to reciprocate ties, or the 'attribute alter' effect, which indicates whether actors with higher values for an attribute (e.g. participation in the research project) receive more nominations from others. The strength of each effect is estimated using a simulation-based approach (Ripley et al., 2019). The parameter represents the log-probabilities of change, similar to parameters of multinomial logistic regression models.

In our case the main effects included: (1) the effect of participation in the research project on the network, and (2) the effect of participation in the research project on farming practices and information dissemination. To test whether the network and farming practices were interconnected, we also included (3) the effect of farming practices on the network, and (4) the effect of the network on farming practices and information dissemination. Lastly, we included (5) standard structural network effects, which represent basic structures of networks, and (6) effects of geographical distance between farmers, clan, gender and age on the network, as they have been shown to influence networks (Beaman & Dillon, 2018; Matous et al., 2013b; Matous & Todo, 2015; Simpson, 2020). Participation in the research project was coded as 0 for nonparticipation and 1 for participation either as a project garden owner or research assistant. Including project garden owner and research assistant as separate levels led to over-specification of the model and was thus avoided. The researched farming practices of using food waste, animal manure or NPK fertiliser were grouped into one variable called 'Total researched practices' with people who used any of these practices

**TABLE 2** Overview of variables. Variables highlighted in blue are independent variables (first six rows), and unhighlighted variables are dependent variables. Note that in the research project only three farming practices, namely those related to food waste, animal manure and NPK fertiliser, were researched. The other two farming practices, including mulching and the variety of sweet potato planted, were not explicitly researched

Variable	Description of variable	Metric
Time	Indicates whether the interview was conducted before or after the research project had been conducted.	Factor Time 1   Time 2
Project	Describes whether someone was not involved in the research project, involved as a project garden owner or involved as a research assistant.	Factor Not involved   Project garden owner   Research assistant
Gender	Specifies whether the interviewee identified as a man or a woman.	Factor Man   Woman
Age	Indicates the interviewee's age in years in 2019.	Continuous
Location	Shortest distance in meters between houses of respondents.	Continuous
Clan	Describes the clan the interviewee was part of.	Factor Clan 1   Clan 2   Clan 3   Clan 4
<i>Researched farming practices</i>		
Food waste	Specifies whether respondents applied food waste on their plots.	Factor No   Yes
Animal manure	Specifies whether respondents used animal manure.	Factor No   Yes
NPK fertiliser	Specifies whether respondents used NPK fertiliser.	Factor No   Yes
<i>Non-researched farming practices</i>		
Mulching	Specifies whether respondents used mulching.	Factor No   Yes
Variety	Specifies if after the research project had been conducted (time 2), respondents started planting the specific variety of sweet potato planted in the experimental gardens.	Factor No   Yes
<i>Information dissemination</i>		
Learned	Whether respondents stated that they had learned something from the research project (at time 2).	Factor No   Yes
<i>Network</i>		
In-degree	In-degree is the number of people in the network that identified the focal respondent as an information source for farming.	Continuous
Out-degree	Out-degree is the number of people named by the focal respondent as information sources for farming.	Continuous

scored as 1, and those who did not scored as 0. This was because too few people adapted animal manure or NPK fertiliser over the course of the project and including them as separate practices led to non-convergence of the model. A full list of the effects included and their descriptions is provided in Appendix, Tables 1 and 2, with code deposited at: <https://data.mendeley.com/datasets/ft8gb8cn5b/1>.

The full SAOM with both network and behaviour data showed that there were no significant relationships between farmers' social network and behaviour (Appendix, Table 3). This allowed us to analyse the network data and behaviour data separately and more in depth. To better understand the structure of the social network, we re-ran the SAOM, but with only the network part, which included: (1) effects of participation in the research project on the network, (2) standard structural network effects, and (3) effects of geographical distance between farmers, clan, gender and age on the network. This time we coded participation as a dummy variable in which we

represented nonparticipants, project garden owners and research assistants separately (Appendix, Table 2).

To further understand the effect of the research project on farmer behaviour and information dissemination, we used logistic regressions. The use of food waste, mulching, starting to plant the research project's specific variety of sweet potato and having learned from the project were the dependent variables. Participation in the project as nonparticipant, project garden owner or research assistant was an independent variable. We included an interaction between participation and time in the case of using food waste or mulching. For starting to plant the project's specific variety of sweet potato and learning, time was not included as these were only relevant during the second survey. Gender was also included as an independent variable, as the adoption of farming practices may differ between men and women (Farnworth et al., 2016). Including two data points from the same household leads to pseudo-replication, so

we included household number as a random effect. However, model results did not significantly change (Appendix, Table 4), so we report here on the simpler model without household number as a random effect. For a full overview of the models run, see Appendix, Table 5.

A general linear model with a binomial error structure was fitted to the data using the 'glm' function in R. We checked for over-dispersion by calculating the ratio between residual deviance and degrees of freedom. If the ratio was  $>1.2$  or  $<0.8$  the model was re-fitted with a quasi-binomial distribution. We report values from the full models because we only included a few unrelated independent variables and thus model simplification was unnecessary. These models were not run for the farming practices of using animal manure and NPK fertiliser, as there was too little variation in the data, thus running statistical analyses would be inappropriate. Instead, the results for these farming practices are described qualitatively.

### 3 | RESULTS

Results from the experimental gardens showed that using NPK fertiliser and chicken manure, but not banana peel compost, improved soil quality and enhanced sweet potato yields (Hazenbosch et al., 2021). The effect of mulching and the variety of sweet potato planted were not researched.

#### 3.1 | Changes in farming practices

Before the start of the research project, the researched farming practices were not used by many farmers: 19% of farmers used food waste in their gardens, 5.3% animal manure and none NPK fertiliser (Table 3). Mulching, however, was a popular practice among 72% of the farmers, especially women (Table 4). There was a tendency, significant at the  $p < 0.1$  level, for project garden owners to use food waste and research assistants to use mulching compared to nonparticipants (Table 4).

Farmers' behaviour changed over time (Table 3). For the researched farming practices, there was a significant increase in the number of farmers who used food waste during the second survey

(Table 4). Whether people started to use food waste was not linked to their involvement in the research project, as project garden owners and research assistants were not more or less likely to adopt these practices compared to nonparticipants (Table 4). Farmers did not use animal manure or NPK fertiliser more often during the second survey. Farmers gave as their main reason for this that they lacked knowledge about how to apply these fertilisers. In addition, farmers mentioned that they may not have access to animal manure or NPK fertiliser, that using these techniques was too much extra work, or that they were afraid that using these fertilisers may negatively affect their physical health.

There was an increase in the uptake of farming practices that were not explicitly researched during the project (Table 3). Significantly more farmers started to mulch. Similarly to the use of food waste, whether people started to mulch was not dependent on their involvement in the research project (Table 4). Some farmers started to plant the specific variety of sweet potato that was also planted in the experimental gardens. Research assistants were more likely than nonparticipants, and women were more likely than men, to start planting the project's variety of sweet potato (Table 4).

All project garden owners and 13 out of 14 research assistants said that they had learned from the research project, which was significantly higher than nonparticipants. Those who had learned something said that they had learned that food waste, animal manure and NPK fertiliser can be used to enhance soil quality, and how to apply these fertilisers. Four people also mentioned that they now knew how to better manage their land.

#### 3.2 | Changes in the social network

The structure of the social network among farmers in Ohu was sparse and clustered, and dynamic between the two time points (Table 5 and Figure 1). Both during the first and second survey people considered, on average, one to two other people as important sources of information when it comes to farming (Table 5). However, some did not find anyone in the group to be an important source,

**TABLE 3** Change in farming practices. Numbers of respondents using a specified practice at time 1 and time 2 are displayed. Total sample size consisted of 57 participants

	Non-participants		Project garden owners		Research assistants	
Researched farming practices						
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2
Food waste	4	14	4	5	3	3
Animal manure	0	6	2	1	1	1
NPK fertiliser	0	0	0	0	0	1
Non-researched farming practices						
Mulching	21	28	9	8	11	13
Variety		2		1		5
Information dissemination						
Learned		7		10		13



		Food waste	Mulching	Sweet potato variety	Learned
Project	Non-participant				
	Project garden owner	(+)	ns	ns	+++
	Research assistant	ns	(+)	++	+++
Time	Time 1				
	Time 2	++	+		
Gender	Man				
	Woman	ns	+++	+	ns
Project × Time	Non-participant: Time 1				
	Garden owner: Time 2	ns	ns		
	Research assistant: Time 2	ns	ns		

**TABLE 4** Dynamics of farming behaviour and information dissemination from time 1 to time 2. Ns = nonsignificant, (+)/(-) =  $p < 0.1$ , +/- =  $p < 0.05$ , ++/-- =  $p < 0.01$ , +++/--- =  $p < 0.001$ , with + indicating a positive effect and - a negative effect. Reference levels are given in grey shading for each variable (first rows). For full results, see Appendix, Table 6

**TABLE 5** Properties of the network

	Time 1	Time 2
Total number of ties in the network	88	110
Network density	0.028	0.034
Mean in/out-degree	1.5	1.9

while one person nominated five people. Similarly, the typical person was considered an important source of information on farming by one to two other group members. Again, some people were not nominated while one person was nominated by seven other people. The network also was highly dynamic. Out of the 88 bonds mentioned during the first survey only 54 were still present during the second survey, and 56 new bonds were formed (Table 5).

The network was characterised by a flat structure in which there were no clear opinion leaders. The strong negative outdegree effect indicates that farmers were not inclined to form bonds with others. Farmers were primarily keen to engage in bi-directional exchanges and to share information within closed clusters, as indicated by the positive reciprocity and transitive ties effects (Table 6). People were more like to form a bond with someone who lived close to them or who was from the same clan (Table 6). There was a tendency, significant at the  $p < 0.1$  level, for men to form bonds with other men and women with women (Table 6).

The main change in the network from the first to the second survey was related to participation in the research project. Those farmers who were selected as research assistants were more sought-after by others for farming advice compared to nonparticipants at the time of the second survey compared to the first survey (Table 6). Project garden owners, however, did not get nominated more often during the second survey compared to the first.

## 4 | DISCUSSION

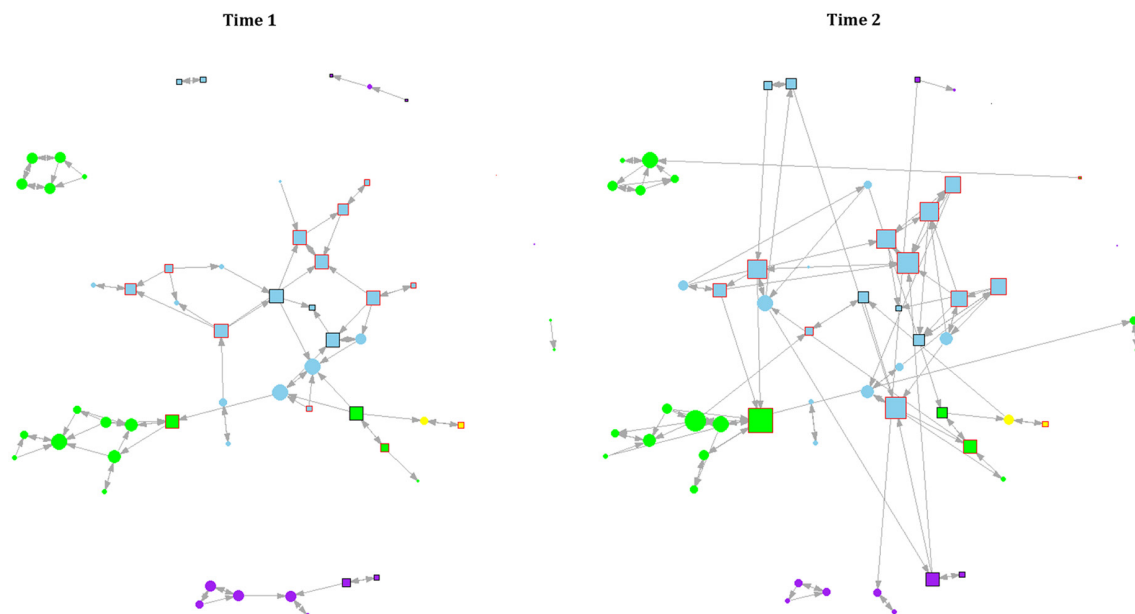
While the agroecological research project was ongoing, local farming practices and the community's social network changed, and not in ways that were predicted based on the aims and activities of the

project. With no obvious other reasons why these practices and the network changed, we infer that the presence of the research team was a causative influence. These results challenge often-held assumptions about social impact and dissemination of agricultural practices by agroecological researchers and advocates. They provide insights into what type of agricultural innovations are more likely to be accepted among farmers, and, to some extent, how practices may most effectively be promoted within a community.

### 4.1 | Changing farming practices

Over the course of the project, farmers changed their farming practices. More people started to use food waste, which corresponded to the banana peel composted treatment which was researched in the experimental gardens. People also took up farming practices that were not directly researched, such as mulching, and started to plant the specific variety of sweet potato that was used in the experimental gardens. These farming practices were especially popular among women. Applying animal manure and NPK fertiliser, on the other hand, were not widely taken up.

While the experiment was running, the research team did not know whether the tested fertilisers would indeed increase yields. Thus none of the fertilisers were actively promoted during this time. Despite this, some farmers created meaning from the researchers' presence in the community, similar to participants in the study described by Hakkarainen et al. (2019). This may in part be caused by the fact that some members of the research team were expatriates who were perceived as 'experts' with access to knowledge, which is regarded highly, especially in PNG (West, 2006). The fact that the research team was working under the banner of a well-established NGO in Ohu, may also have contributed to the quick uptake of new practices by farmers. Usmani et al. (2021) uncovered a large and positive 'NGO effect' in which a local NGO's prior engagement with a community increases the effectiveness of a technology intervention implemented by it by at least 30%. As it turns out, applying banana peel compost did not have a positive effect on sweet potato yields (Hazenbosch et al. 2021), and we did not investigate the effect of mulching or the impact of the



**FIGURE 1** Visualisation of the social network at time 1 (left) and time 2 (right). Each node represents an actor in the network with the size of the node representing the importance of the actor based on their average in/out-degree. Each arrow represents a link and points from a respondent to an important source of information. The colours indicate different clans with clan 1 being purple, clan 2 green, clan 3 blue and clan 4 yellow. Circles indicate nonparticipants, whereas squares represent nodes who were involved in the research project, with squares with black borders indicating project garden owners and squares with red borders indicating research assistants.

**TABLE 6** Dynamics of the network. (+)/(-) =  $p < 0.1$ , +/- =  $p < 0.05$ , ++/-- =  $p < 0.01$ , +++/--- =  $p < 0.001$ , with + indicating a positive effect and - a negative effect. The estimate shows the change between the two surveys in the effect of the variable. Here we display only the effects of interest. For a table of the full model and the model's goodness of fit, see Appendix, Table 7

	Description	Estimate	Standard error	p-level
<i>Structural network effects</i>				
Outdegree	Overall information-seeking activity	-2.3746	0.7073	---
Reciprocity	Mutual information exchange	1.7578	0.3358	+++
Transitive ties	Clustering of information network	0.6821	0.2078	++
Distance	Geographical proximity influences tie formation	-0.0020	0.0005	---
Same clan	Preference for advisors from same clan	0.8106	0.3290	+
Gender with $\varphi = 1$				
Ego	Tendency for women to seek more information	0.2510	0.3154	
Alter	Preference for female advisors	-0.5416	0.2746	-
Same	Preference for advisors from same gender	0.4663	0.2501	(+)
Project garden owner				
Ego	Tendency for project garden owners to seek more information	-0.1309	0.4287	
Alter	Preference for advisors who are project garden owners	0.2593	0.4260	
Same	Preference of project garden owners toward project garden owners	-0.0936	0.4159	
Project research assistant				
Ego	Tendency for research assistants to seek more information	0.4926	0.3689	
Alter	Preference for advisors who are research assistants	0.8816	0.3349	++
Same	Preference of research assistants toward research assistants	-0.2459	0.2491	



variety of sweet potato planted. So created meanings can be unexpected and have unintended effects on the community.

Created meanings may not only influence the society, but also the research itself. In the experimental gardens we planted the 'wan mun kaukau' sweet potato variety, following the advice of a local farmer. Only after the project had finished, did the farmer tell us that she had not been sure that the variety would grow well. However, she had thought that one of the contributions the research could make was establishing whether 'wan mun kaukau' would be a good variety to grow, something that the research team had not intended to investigate. It is not often that natural scientists reflect upon how their research 'subjects' may turn the tables on them and influence researchers unintentionally to carry out research that they are interested in. Reflecting on this may allow agroecologists to develop a sharper sense of reality, and perhaps help tailor their research to answer questions that local people are interested in.

Looking at which farming practices were taken up provides insights into what type of agricultural innovations are likely to be accepted among farmers (Garnett et al., 2009). Innovations that do not require fundamental changes in people's behaviour are usually much more readily accepted (Rogers, 2003). Mulching is traditionally practised in this community. Replacing grass, leaves or plant residue mulches with food waste was relatively easy, and this may explain why more farmers started to apply food waste (expanding the researched banana peels to include a range of other food waste products). Likewise, farmers in PNG already plant a great variety of crops (Bourke & Harwood, 2009), so switching the variety of sweet potato was also relatively easy. In a similar way, white yam (*Dioscorea rotundata*) was introduced to PNG in 1986 and has been steadily adopted by farmers, which is often explained by the fact that white yam has many similarities to the traditionally-grown greater yam (*Dioscorea alata*) (Risimeri et al., 2001).

Applying animal manure and NPK fertiliser required new knowledge and inputs. Farmers indicated that despite the research intervention they did not think they had enough knowledge and practical experience yet to start using these fertilisers. They also thought it too difficult to acquire the necessary materials; collecting animal manure requires farmers to buy and fence animals and getting NPK fertiliser involves going to town, both of which demand time and money. Not having enough knowledge and initial costs are often barriers to innovation among farmers (Piñeiro et al., 2020). Future research that aims to develop and promote agricultural techniques would benefit from harnessing existing practices and optimising them, rather than introducing completely new practices (Rogers, 2003).

## 4.2 | Rewiring information-sharing networks in a smallholder farming community

We found that the research project, at least temporarily, affected the social network in the community. Local community members who were directly involved in the project as research assistants became more sought-after for advice. The intervention provided research

assistants with external information, which may have helped them to increase their prominence. This phenomenon is not unique to PNG. Beaman et al. (2020) found that farmers in Malawi who had received training had on average more conversations than control farmers, and similarly Matous and Wang (2019) reported that farmers in Sumatra gained higher levels of influence in their communities after attending training events. In our project, however, project garden owners did not get nominated more often despite also being given information about the research, and garden owners themselves indicating that they had learned from the project. However, they received little hands-on experience and played a less prominent role in the research project overall, which may have made them less attractive advisors.

Our results demonstrate the importance of being mindful about who gets involved in a project. The choice of who to involve has implications for who will benefit, as also argued by Beaman and Dillon (2018). Researchers and advocates often collaborate with local leaders or elites as they are seen as gatekeepers to the resources needed to successfully complete the project (Toomey, 2016). This can be appropriate, but there may be a risk of reinforcing existing social structures and further marginalising people on the periphery (Beaman & Dillon, 2018; Matous & Wang, 2019), which could ultimately lead to tensions within the community, and between external actors and local community members (West, 2006). Conversely, many donors require a focus on involving marginalised groups (e.g. women or youth). This too could lead to tensions through perceived threats to the established order. Project leads should thus think carefully about who gets involved, and aim to increase inclusivity in a culturally appropriate manner.

Examining the dynamics of social networks with respect to dissemination can also provide valuable information. Based on our findings it seems unlikely that relying on social networks to spread information and farming practices will always be successful in PNG. In Ohu, the learning network between farmers was decentralised and clustered based on geographical location and clan identity. People in PNG strongly identify with their clan, as clan membership allows people access to clan-owned land and gives people protection from external threats. Clan membership ties people to geographical locations, and limits movement as you need permission to access other people's land (Bourke & Harwood, 2009). This, combined with limited access to transportation facilities, may cause social ties to decrease when geographic distance between people increases, similar to findings from Ethiopia (Matous et al., 2013b). There is often competition for land-use rights and other resources among neighbouring clans, and even within a clan there may be competition among nuclear families (Baynes et al., 2017). Hence, people may be reluctant to share information, including information about farming practices or a research project, outside their close family. Therefore, it cannot be assumed that in PNG trained farmers will influence others. Instead, agroecological extension officers would benefit from identifying and targeting connected clusters of individuals at the start of an intervention, as this has

been shown to be a highly effective strategy for diffusing behaviours (Centola, 2018). If resources are not sufficient to collect social network data to identify clusters, investing in reaching out to more farmers individually could be the next best strategy (de Lange et al., 2021).

## 5 | CONCLUSIONS

We show that agroecological research can actively shape individuals' behaviours and a community's social network. Agroecological researchers therefore need to move away from the idea that they are neutral parties shielded by the objectivity of science (Brittain et al., 2020). Instead, researchers should envision impact as an ongoing emergent property throughout their project (Toomey et al., 2017). Agroecological advocates, on the other hand, require a solid understanding of how social networks spread the desired information and farming practices so that they can use them effectively; in our case, information did not spread much beyond targeted farmers. Care should also be taken, by both agroecological researchers and advocates, about who to involve in a project, because this has consequences for who gains. Although these lessons may be well understood by some, there are few detailed empirical case studies that demonstrate them. Future work might usefully explore these dynamics in an experimental setting, for example through comparing villages in which information sharing was or was not actively promoted. It may also be of interest to include neighbouring villages in the study to better understand how far the effects of knowledge transfer reach. Overall, our case study illustrates the need for agroecological researchers and advocates to think carefully about whether their assumptions are valid about how, when and what parts of their activities will translate into practice. This can help them to work more effectively toward their goal of solving challenges in agricultural production.

## AUTHOR CONTRIBUTIONS

Mirjam Hazenbosch, E.J. Milner-Gulland, Shen Sui, Brus Isua, Emilie Beauchamp and Rebecca J. Morris conceived the project and designed the study. Mirjam Hazenbosch, Shen Sui, Brus Isua, Alfred Kik, Grace Luke and Jason Paliau collected the data. Mirjam Hazenbosch and Petr Matouš conducted data analysis, and all authors contributed to interpretations of the results. Mirjam Hazenbosch wrote the manuscript with input from all authors.

## ACKNOWLEDGEMENTS

We are in great debt to farmers in Ohu who gave up their time for our interviews, and to landowners who allowed us to set up experimental gardens. We are also very grateful for the support from staff of The New Guinea Binatang Research Centre, Dr Francesca Dem and Professor Vojtěch Novotný. We thank Dr Emiel de Lange for insightful discussions. This project was financially supported by the Biotechnology and Biological Sciences Research Council (BBSRC) [grant number BB/M011224/1].

## CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to ethical restrictions. The computer code that support the findings of this study is available from <https://doi.org/10.17632/ft8gb8cn5b.1>.

## ORCID

Mirjam Hazenbosch  <https://orcid.org/0000-0002-5094-6019>

Shen Sui  <https://orcid.org/0000-0001-9209-6174>

Emilie Beauchamp  <https://orcid.org/0000-0001-9546-987X>

Petr Matouš  <https://orcid.org/0000-0002-6140-6843>

Rebecca J. Morris  <https://orcid.org/0000-0002-0020-5327>

E. J. Milner-Gulland  <https://orcid.org/0000-0003-0324-2710>

## REFERENCES

- Baynes, J., Herbohn, J., & Unsworth, W. (2017). Reforesting the grasslands of Papua New Guinea: The importance of a family-based approach. *Journal of Rural Studies*, 56, 124–131. <https://doi.org/10.1016/j.jrurstud.2017.09.012>
- Beaman, L. A., BenYishay, A., Magruder, J., & Mushfiq Mobarak, A. (2020). *Can network theory-based targeting increase technology adoption? National Bureau of Economic Research Working Paper Series*, w24912. <https://doi.org/10.2139/ssrn.3225815>
- Beaman, L. A., & Dillon, A. (2018). Diffusion of agricultural information within social networks: Evidence on gender inequalities from Mali. *Journal of Development Economics*, 133, 147–161. <https://doi.org/10.1016/j.jdeveco.2018.01.009>
- Bertuol-Garcia, D., Morsello, C., El-Hani, C. N., & Pardini, R. (2018). A conceptual framework for understanding the perspectives on the causes of the science–practice gap in ecology and conservation. *Biological Reviews*, 93(2), 1032–1055. <https://doi.org/10.1111/brv.12385>
- Bourke, R. M., & Harwood, T. A. (Eds.). (2009). *Food and agriculture in Papua New Guinea*. ANU E Press.
- Brittain, S., Ibbett, H., Lange, E., Dorward, L., Hoyte, S., Marino, A., Milner-Gulland, E. J., Newth, J., Rakotonarivo, S., Verissimo, D., & Lewis, J. (2020). Ethical considerations when conservation research involves people. *Conservation Biology*, 34(4), 925–933. <https://doi.org/10.1111/cobi.13464>
- Centola, D. (2018). *How behavior spreads: The science of complex contagions*. Princeton University Press.
- de Lange, E., Dobson, A. D. M., Milner-Gulland, E. J., & Keane, A. (2021). Combining simulation and empirical data to explore the scope for social network interventions in conservation. *Biological Conservation*, 261, 109292. <https://doi.org/10.1016/j.biocon.2021.109292>
- de Lange, E., Milner-Gulland, E. J., & Keane, A. (2019). Improving environmental interventions by understanding information flows. *Trends in Ecology & Evolution*, 34(11), 1034–1047. <https://doi.org/10.1016/j.tree.2019.06.007>
- Farnworth, C. R., Baudron, F., Andersson, J. A., Misiko, M., Badstue, L., & Stirling, C. M. (2016). Gender and conservation agriculture in east and southern Africa: Towards a research agenda. *International Journal of Agricultural Sustainability*, 14(2), 142–165. <https://doi.org/10.1080/14735903.2015.1065602>

- Garnett, S. T., Crowley, G. M., Hunter-Xenie, H., Kozanayi, W., Sithole, B., Palmer, C., Southgate, R., & Zander, K. K. (2009). Transformative knowledge transfer through empowering and paying community researchers. *Biotropica*, 41(5), 571–577. <https://doi.org/10.1111/j.1744-7429.2009.00558.x>
- Genius, M., Koundouri, P., Nauges, C., & Tzouvelekas, V. (2014). Information transmission in irrigation technology adoption and diffusion: Social learning, extension services, and spatial effects. *American Journal of Agricultural Economics*, 96(1), 328–344. <https://doi.org/10.1093/ajae/aat054>
- Groce, J. E., Farrelly, M. A., Jorgensen, B. S., & Cook, C. N. (2018). Using social-network research to improve outcomes in natural resource management. *Conservation Biology*, 33(1), 53–65. <https://doi.org/10.1111/cobi.13127>
- Hakkarainen, V., Daw, T. M., & Tengö, M. (2019). On the other end of research: Exploring community-level knowledge exchanges in small-scale fisheries in Zanzibar. *Sustainability Science*, 15, 281–295. <https://doi.org/10.1007/s11625-019-00750-4>
- Hazenbosch, M., Sui, S., Isua, B., Beauchamp, E., Frouz, J., Imale, K., Jimbudo, M., Milner-Gulland, E. J., Novotný, V., Veselá, H., & Morris, R. J. (2021). Using locally available fertilisers to enhance the yields of swidden farmers in Papua New Guinea. *Agricultural Systems*, 192, 103089. <https://doi.org/10.1016/j.agsy.2021.103089>
- Isaac, M. E., Nyantakyi-Frimpong, H., Matouš, P., Dawoe, E., & Anglaaere, L. C. N. (2021). Farmer networks and agrobiodiversity interventions: The unintended outcomes of intended change. *Ecology and Society*, 26(4). <https://doi.org/10.5751/ES-12734-260412>
- Matous, P., & Todo, Y. (2015). Exploring dynamic mechanisms of learning networks for resource conservation. *Ecology and Society*, 20(2). <https://doi.org/10.5751/ES-07602-200236>
- Matous, P., Todo, Y., & Mojo, D. (2013a). Roles of extension and ethno-religious networks in acceptance of resource-conserving agriculture among Ethiopian farmers. *International Journal of Agricultural Sustainability*, 11(4), 301–316. <https://doi.org/10.1080/14735903.2012.751701>
- Matous, P., Todo, Y., & Mojo, D. (2013b). Boots are made for walking: Interactions across physical and social space in infrastructure-poor regions. *Journal of Transport Geography*, 31, 226–235. <https://doi.org/10.1016/j.jtrangeo.2013.04.001>
- Matous, P., & Wang, P. (2019). External exposure, boundary-spanning, and opinion leadership in remote communities: A network experiment. *Social Networks*, 56, 10–22. <https://doi.org/10.1016/j.socnet.2018.08.002>
- Pamphilon, B., & Mikhailovich, K. (2017). Bringing together learning from two worlds: Lessons from a gender-inclusive community education approach with smallholder farmers in Papua New Guinea. *Australian Journal of Adult Learning*, 57(2), 172–196.
- Piñero, V., Arias, J., Dürr, J., Elverdin, P., Ibáñez, A. M., Kinengyere, A., Opazo, C. M., Owoo, N., Page, J. R., Prager, S. D., & Torero, M. (2020). A scoping review on incentives for adoption of sustainable agricultural practices and their outcomes. *Nature Sustainability*, 3(10), 809–820. <https://doi.org/10.1038/s41893-020-00617-y>
- R Core Team. (2020). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. <http://www.r-project.org/>
- Ripley, R. M., Snijders, T. A. B., Boda, Z., Vörös, A., & Preciado, P. (2019). *Manual for RSIENA version 4.0*. University of Oxford, Department of Statistics, Nuffield College.
- Risimeri, J. B., Gendua, P. A., & Maima, J. B. (2001). The status of the introduced white yam in Papua New Guinea. In R. M. Bourke, M. G. Allen, & J. G. Salisbury (Eds.), *Food security in Papua New Guinea*. Australian Centre for International Agricultural Research.
- Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.
- Shackleton, C. M., Cundill, G., & Knight, A. T. (2009). Beyond just research: Experiences from southern Africa in developing social learning partnerships for resource conservation initiatives. *Biotropica*, 41(5), 563–570. <https://doi.org/10.1111/j.1744-7429.2009.00559.x>
- Simpson, C. R. (2020). Farm size shapes friend choice amongst rice producers in China: Some evidence for the theory of network ecology. *Social Networks*, 61, 107–127. <https://doi.org/10.1016/j.socnet.2019.10.001>
- Snijders, T. A. B., van de Bunt, G. G., & Steglich, C. E. G. (2010). Introduction to stochastic actor-based models for network dynamics. *Social Networks*, 32(1), 44–60. <https://doi.org/10.1016/j.socnet.2009.02.004>
- Toomey, A. H. (2016). What happens at the gap between knowledge and practice? Spaces of encounter and misencounter between environmental scientists and local people. *Ecology and Society*, 21(2), 1–19. <https://doi.org/10.5751/ES-08409-210228>
- Toomey, A. H., Knight, A. T., & Barlow, J. (2017). Navigating the space between research and implementation in conservation. *Conservation Letters*, 10(5), 619–625. <https://doi.org/10.1111/cons.12315>
- Usmani, F., Jeuland, M., & Pattanayak, S. K. (2021). NGOs and the effectiveness of interventions. *Ruhr Economic Papers*, 902. <http://doi.org/10.2139/ssrn.3200187>
- van Kerkhoff, L. E., & Lebel, L. (2015). Coproductive capacities: Rethinking science-governance relations in a diverse world. *Ecology and Society*, 20(1), 1–6. <https://doi.org/10.5751/ES-07188-200114>
- Weiblen, G. D., & Moe, A. (2016). *WIAD conservation—A handbook of traditional knowledge and biodiversity*. University of Minnesota Printing Services.
- West, P. (2006). *Conservation is our government now: The politics of ecology in Papua New Guinea*. Duke University Press.
- Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., & David, C. (2009). Agroecology as a science, a movement and a practice. *Sustainable Agriculture*, 2, 27–43. [https://doi.org/10.1007/978-94-007-0394-0\\_3](https://doi.org/10.1007/978-94-007-0394-0_3)

## DATA SOURCES (FOR APPENDIX, SECTION 2)

- Block, P., Stadtfeld, C., & Snijders, T. A. B. (2019). Forms of dependence: Comparing SAOMs and ERGMs from basic principles. *Sociological Methods and Research*, 48(1), 202–239. <https://doi.org/10.1177/0049124116672680>
- Lospinoso, J. (2012). *Statistical models for social network dynamics*. University of Oxford.
- Lusher, D., Koskinen, J., & Robins, G. (2013). *Exponential random graph models for social networks: Theory, methods and applications*. Cambridge University Press. <https://doi.org/10.1017/CBO9780511894701>
- Ripley, R. M., Snijders, T. A. B., Boda, Z., Vörös, A., & Preciado, P. (2019a). *Manual for RSIENA version 4.0*. University of Oxford, Department of Statistics, Nuffield College.

## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

**How to cite this article:** Hazenbosch, M., Sui, S., Isua, B., Beauchamp, E., Kik, A., Luke, G., Matouš, P., Morris, R. J., Paliau, J., & Milner-Gulland, E. J. (2022). Quantifying unintended effects of an agroecological research project on farmers' practices and social network in Papua New Guinea. *People and Nature*, 4, 1592–1602. <https://doi.org/10.1002/pan3.10404>