The times are changing: understanding past, current and future resource use in rural Papua New Guinea using participatory photography

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Highlights

- Local people's voices need to be included in research and planning processes using inclusive and innovative methods.
- We used participatory photography to capture local perspectives on resources, changes and adaptations in Papua New Guinea.
- Results show that villagers are facing rapid social-ecological changes, including growing populations, more cash crop diseases and land shortages.
- People have adapted by shifting to well yielding crop species, setting up small businesses and aiming to get an education.
- Results can be used in future research and planning processes in Papua New Guinea.

Abstract

1. There is a need to include local people's voices in research and planning processes to better understand what they see as opportunities and challenges for their future. This is necessary because of the intrinsic importance of public participation, and because it can help produce more useful and implementable adaptation plans.
2. We apply participatory photography in a Papua New Guinean smallholder farming community to explore local perspectives on resource management, drivers of change and adaptive strategies.
3. Twenty-four farmers of different clans, genders and ages took photos of items important to their livelihoods, focusing separately on the past, present and future. We discussed the photos and their meanings in individual and group interviews, encouraging farmers to lead the conversations.
4. Results show that farmers are shifting from relying mainly on natural capitals to using financial, social and physical capitals, and that this causes changes in people's well-being. Villagers see cash crop diseases, land shortages and lack of training as their main challenges. So far, people have adapted to changes by shifting to crop species that still yield well, and setting up small businesses and projects to have additional sources of income. Farmers see education as key to their future as it would allow for better land management and diversification of livelihoods.
5. The participatory photography process provided triangulation of scientific studies, gave insights into farmers' perceptions, and highlighted adaptive strategies and the complexities of realising them. Overall, the results can be used in future research and planning processes in Papua New Guinea.

Keywords

Adaptive strategies, biodiversity conservation, local knowledge, smallholder agriculture, social-ecological change, well-being

1. Introduction

People are inextricably linked to their environment through their dependence on resources and ecosystem services (Millennium Ecosystem Assessment, 2005). Especially in rural and low-income areas of the world, people rely heavily on natural resources for their livelihoods and well-being (Fisher et al., 2014). A growing body of conceptual frameworks and empirical research (e.g. TEEB (2010), Díaz et al. (2015), Fisher et al. (2014), Summers et al. (2012), Cruz-Garcia et al. (2017)) shows how ecosystem services, such as soil formation, food, water purification and spiritual fulfilment, contribute to human physical, physiological and psychological well-being (King et al., 2014).

Increasingly, many rural and low-income communities are impacted by social and ecological changes (Bennett et al., 2016; Masterson et al., 2018). These include, for example, growing populations, shifts to new livelihoods, climate change, external actors moving into their area, and changes in regulatory frameworks. Communities need to respond to these changes, and the extent to which they are able to do this has implications for both well-being and environmental sustainability (Bennett & Dearden, 2013).

There is an increasing recognition of the need to engage local and indigenous groups on their own terms, and have them fully participate in research and planning processes aimed at supporting their communities to address rapid and ongoing social-ecological changes (Heiner et al., 2019; Mistry & Berardi, 2016). This is necessary because of the intrinsic importance of public participation, and because it can help produce assessments and adaptation plans that are useful and implementable (Bennett et al., 2016). Specifically, local perspectives can help triangulate and expand scientific knowledge (Bennett & Dearden, 2013). Insights from indigenous knowledge and perspectives in regard to ecosystem management are also of interest, as indigenous groups have resource-use practices that are tailored to work in complex ecological systems (Berkes & Berkes, 2009; Heiner et al., 2019), and local communities tend to look for holistic solutions to emerging issues (Mistry & Berardi, 2016). Additionally, involving local actors makes research and planning processes more

acceptable to the societies that they seek to support, while promoting social justice (Pascoe et al., 2019) and establishing self-determination as a key principle of engagement (Mistry & Berardi, 2016). Local perspectives may be diverse as communities are not homogenous, however (Klein et al., 2014). It is thus important to engage with a range of local actors to capture as many voices as possible. Participatory methods have been developed to incorporate community knowledge, preferences and values into research and planning processes (Masterson et al., 2018).

One participatory method that has been successful in actively involving participants, highlighting multiple perspectives, promoting dialogue, and informing policy, is participatory photography (Wang & Burris, 1997). In participatory photography people photograph their everyday lives, and the photos are subsequently used to identify people's perspectives and challenges, catalysing conversations and encouraging action. Participatory photography has been successfully applied, especially within anthropology, sociology and cultural studies (Harper, 2002), and public health (Catalani & Minkler, 2010). In the literature it has taken various forms, such as photo elicitation, autodriven photo elicitation, photo-elicitation interviews, photo novella, photo interviewing and reflexive photography or autodriving (Gotschi et al., 2009). The different forms of participatory photography differ in their goal of either informing research (such as photo elicitation) or promoting social action (such as photovoice). What binds the different concepts together is that the active role of participants is emphasized in the generation and interpretation of photos (Gotschi et al., 2009).

Increasingly, participatory photography is being used in resource management research and planning. The method has been applied, for example, to examine the links between the environment and human well-being (Masterson et al., 2018), the social and ecological changes that are affecting these relationships (Baldwin & Chandler, 2010; Bennett & Dearden, 2013), and how communities are responding (Bennett & Dearden, 2013). Benefits of using participatory photography in this field are that the visual form of communication inherent to participatory photography allows those things to be captured which may evade textual description, and thus can lead to richer data compared with exclusively verbal methods (Pain, 2012). It helps overcome researchers' preconceived notions, and

generates local, comprehensive and more emotional perspectives on nature's intrinsic and cultural values which are otherwise hard to obtain (Masterson et al., 2018). Participatory photography also allows participants to become researchers and advocates for their own circumstances and to take ownership of the project, thereby opening up spaces for self-driven discussions of the future (Jenkins & Boudewijn, 2020).

We apply participatory photography in a smallholder farming community in Papua New Guinea (PNG) to explore local perspectives on resource management, drivers of change in resource use and availability, along with their responses to those changes. More than 75% of the population in PNG depends almost entirely on swidden agriculture (Conservation and Environment Protection Authority, 2019). Current social-ecological changes, which include ecosystem changes, population growth and shifts to new livelihoods, are posing risks to the well-being, health and food security of swidden farmers in PNG (Bourke & Harwood, 2009). PNG's government has developed a long-term vision, *PNG Vision 2050*, which hopes to address these changes (National Strategic Plan Taskforce, 2011). If *Vision 2050* is to be successfully implemented it will need to engage local actors, as PNG is one of the few countries where customary ownership of land and its resources is recognised under the nation's Constitution and 97% of the land is under customary land tenure (Anderson, 2010).

Photographs can serve as a starting point for discussions about resource management and social-ecological changes by farmers in PNG. By giving voice to local people's perspectives, this research contributes to better understanding of resource management, social-ecological changes and adaptive capacities in farming communities in PNG.

2. Materials and Methods

2.1 Social-cultural context of Papua New Guinea

Eighty-seven percent of the people in PNG live in rural regions in small communities of a few hundred villagers (Oakland Institute, 2013; The World Bank Group, 2020). People usually live with their 'wantoks', which translates to 'one-talks'. Wantoks are groups of individuals who share a similar linguistic background, a common geographical area or an ethnic origin (Nanau, 2011), and often belong to the same clan or tribe (Baynes et al., 2017). They are bound together by the principle of mutual reciprocity, and are expected to take care of each other and jointly participate in socio-political, economic, traditional and cultural activities. The wantok system provides social support, but also comes with obligations to look after one's own group. It is an integral part of PNG's society.

The vast majority of PNG's population depends almost entirely on swidden agriculture (Conservation and Environment Protection Authority, 2019). Swidden agriculture in PNG is practised from sea level to around 2800 m elevation, and farming practices vary from place to place. In general, a nuclear family (usually consisting of five to ten people, including children) will clear and burn up to three small primary or secondary forest areas around their village on land that belongs to their clan. The resulting fields are called 'food gardens' and form the basis of people's livelihoods. In these gardens a combination of food crops, such as sweet potato and banana, is grown (Hazenbosch et al., 2021). In addition, people may prepare a couple of small plots closer to their house where they mainly grow vegetables (Sillitoe, 1999). After 1-5 rounds of crop planting, gardens are usually left to fallow for 5-15 years before they are re-used again (Bourke & Harwood, 2009). Increasingly, cash crops, such as coffee and cacao, are planted alongside food crops, and are mostly sold on informal markets (Bourke & Harwood, 2009). Monetary income has been shown to cause a shift in people's food preferences away from starch-based goods towards more protein-dense food (Schmidt et al., 2020).

Many farmers also harvest fruits and vegetables in adjacent forests to complement their diets (Bourke & Harwood, 2009). Important forest tree crops include Highland kapiak (*Ficus dammaropsis* Diels), kumu musong (*Ficus copiosa* Steud.) and tulip (*Gnetum gnemon* L.). Forests are also used to hunt wild meat, collect building materials and firewood, find plant medicines, and provide spiritual value, among many other things (Bourke & Harwood, 2009).

2.2 Background to Ohu

The project was conducted in Ohu (S 05°13.081', E 145°40.735'), a village located 12 km west from the town of Madang in PNG. Ohu has a long standing collaboration with The New Guinea Binatang Research Centre (NGBRC), a local NGO committed to conducting biological research and conservation in PNG (Weiblen & Moe, 2016). The research team, which consisted of Papua New Guinean and international researchers, had been conducting social-ecological research in Ohu for two years before embarking on the photo project and had thus built up relationships of trust with the participants.

The social-ecological system in Ohu is representative of other landscapes in Madang province and Lowland PNG in general. Farmers use clan-owned land for making their gardens, and grow a combination of food crops (such as banana and sweet potato) and cash crops (such as betel nut and cacao) (Hazenbosch et al., 2021).The original mosaic of primary and secondary forest around the village has changed since the 1980s into a more intensively managed landscape with food gardens, young secondary forest on abandoned food gardens, family plantations and village settlements (Sam et al., 2014).

Some of the remaining fragments of primary forest are being preserved as a village-based protected area, now called WIAD Conservation (Fig. 1). WIAD stands for Watup, Inamus, Asial and Dougu, and refers to the customary lands which are being conserved. Preservation of this area started in the 1950s when people in Ohu became concerned about declines in different species of bird of paradise (family Paradisaeidae), whose feathers they used for traditional dresses, festive dances and

customary gift exchanges. Four clans in Ohu came together to establish an agreement to set aside a part of their customary lands in which hunting, mining, logging and gardening were forbidden. Currently two of these clans are still actively involved in the management of the conservation area.

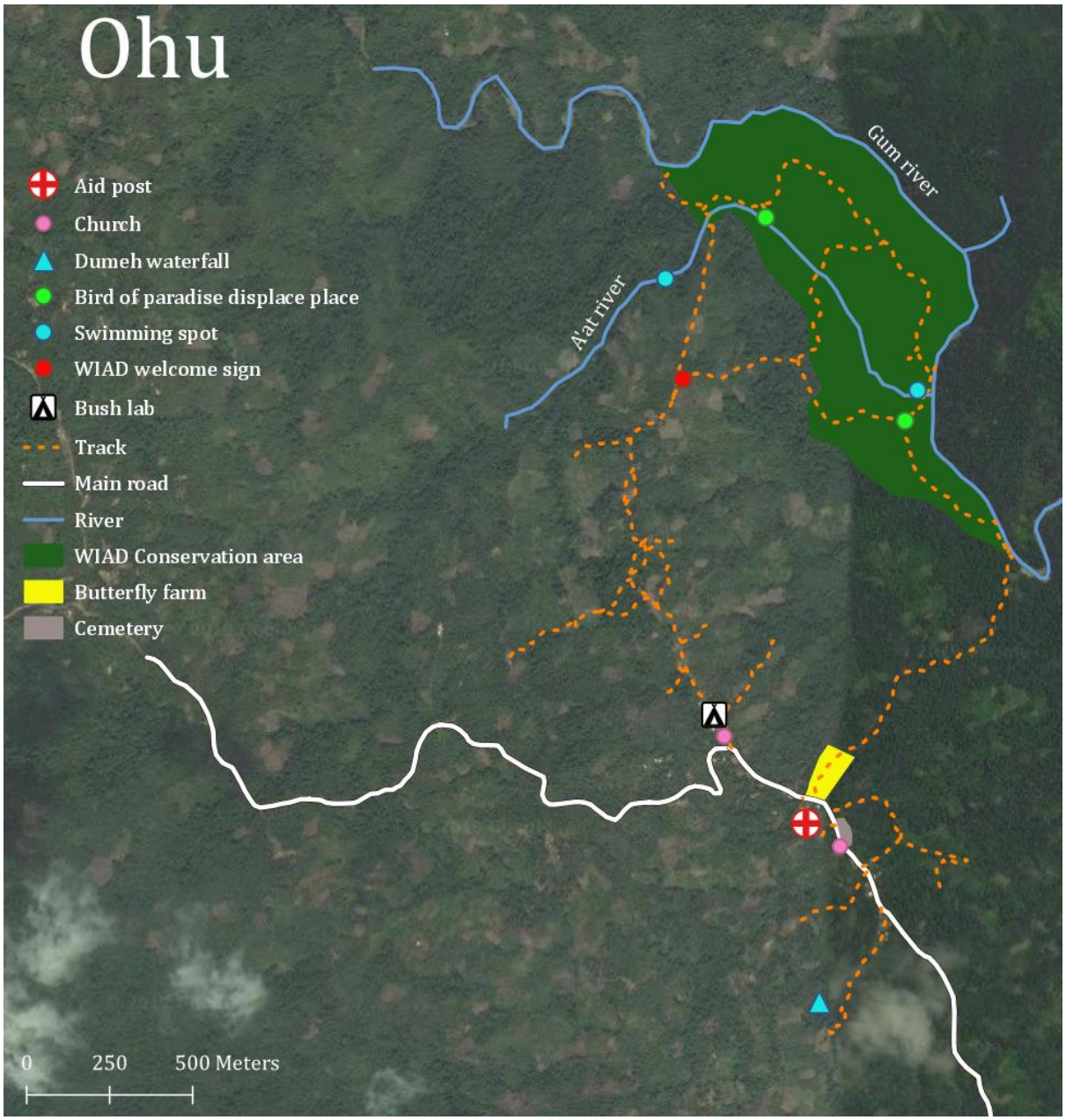


Figure 1: Map of Ohu village and its most prominent features. The WIAD Conservation area is a village-based conservation area. The remaining land is used for swidden agriculture. This map was created and published with permission from Ohu's community leaders.

WIAD Conservation is currently one of the few remaining Lowland rainforests around the town of Madang. It hosts significant biodiversity including the king-bird-of-paradise (*Cicinnurus*

regius), lesser bird of paradise (*Paradisaea minor*) and rare birdwing butterflies. New species are still being discovered at WIAD Conservation, and often named after the place and its people. For example, *Kradibia ohuensis* is a fig pollinator and is named after Ohu, and *Ficobracon brusi* is a parasitoid which is named after one of the co-authors (Van Achterberg & Weiblen, 2000). In collaboration with NGBRC, Papua New Guinean and international researchers often visit Ohu and its conservation area to conduct ecological research, which brings some economic benefits to the village (Weiblen & Moe, 2016).

Ohu is currently undergoing rapid social-ecological changes, including increased connectivity to town, population growth and ecosystem changes, like many villages around Madang (a growing town of currently approximately 30,000 people). How these social-ecological changes affect the livelihoods of local farmers in Ohu has consequences for their well-being and for WIAD Conservation. It is thus of interest to both agricultural development organisations and conservationists to understand what changes are affecting Ohu, how people are responding to them, how local landowners see and plan the future, and how these challenges and adaptations relate to PNG's *Vision 2050*. There is a high level of illiteracy among adults in Ohu due to lack of access to education, so relying on visual and oral forms of communication as done in participatory photography was deemed appropriate.

2.3 Survey

Participatory photography research usually consists of six steps: (1) recruitment of participants, (2) completion of a training workshop, (3) conduction of the photography assignment, (4) interviews based on the photographs, (5) analysis of the main topics and themes, and (6) creation of a public facing output (Bennett & Dearden, 2013; Samuels, 2004; Shaw, 2013). We followed these steps and tailored the exact content and format to the context of Ohu.

A challenging part of conducting the participatory photography project was to ensure that it was ethically appropriate. The research was approved by PNG's National Research Institute, and the

interview protocol was deemed appropriate by the University of Oxford's Research Ethics Committee under permit number R58337/RE004. However, we also had to ensure work was deemed ethically appropriate by people in Ohu. Research may have unintended effects which can positively or negatively affect participants (Hazenbosch et al., in review). We took a 'do no harm' approach in which we thoroughly assessed the local context and ensured that the research did not increase the risk of violence and other adversities as a result of the participatory photography project (Eves et al., 2018). Throughout the methods we describe how we achieved this for each step in the research process.

We asked local village leaders to help us recruit participants in order to respect cultural norms. With their assistance, we recruited 24 local people. Purposeful recruitment was necessary to attract a representative sample from the community (Wang & Burris, 1997). Participants came from three groups; the first and second groups were selected from the two clans that are still heavily involved in the management of WIAD Conservation, and the third was recruited from clans that are less involved in the conservation area (Appendix, Table 1). Groups were kept separate as resources in PNG, including WIAD Conservation, are often contested and we wanted to avoid causing any intra-clan or intra-tribe tensions (Baynes et al., 2017). Within each group we asked both younger (< 40 years) and older (> 40 years) people, and men and women, to participate as relationships with resources in PNG can differ between these groups.

With respect to the second, third and fourth steps, we were aware that being known to be carrying a camera could put the participants at a higher risk of being robbed because cameras are seen as a valuable resource in PNG, similar to Jenkins and Boudewijn's (2020) experience when working with female anti-mining activists in Peru. We thus only asked participants to carry cameras during the day (they returned the cameras at night to the research team) and conducted the photo project over a short period (two weeks) at the end of the two-year research project to minimise risks to both participants and the research team.

We worked with each group over four days. On the first day, a training workshop was organised in which issues of ethics, health and safety, and participants' expectations of the project

were addressed. We also taught participants how to use tablets and how to take photos with them. We chose to use tablets rather than cameras, as tablets allow participants to immediately see their own photo and decide whether they were happy with it. Everyone was given the opportunity to practice using the tablets until they felt comfortable with them. We took ample time for the training part of the project as for many of the participants this was the first time they handled a tablet.

On the second day, we proceeded to step three of the participatory photography process. We asked participants to use their tablets to take photos of 'things on your land that are currently important for the lives of people in your clan'. We specifically encouraged participants to think about their clan rather than their own individual lives so we could get a clan-wide understanding, from the perspective of different groups. We explicitly asked participants to photograph only their own clan resources to avoid creating tensions between clans. We also asked participants to not photograph any people as we could not guarantee that potentially photographed people would be able to give permission for their photo to be taken. Participants could take a maximum of five photos, to allow for the limited battery life of tablets, the amount of photo paper that we could transport, and the time the subsequent interview would take, as participants were busy with their daily lives. People were given as much time as they needed to take photos. Upon their return from the photography assignment, we printed their photos.

We then discussed the printed photos one by one in in-depth, face-to-face, individual interviews. Before commencing any interview, we gained the free, prior and informed consent of respondents. We did this by first explaining who we were, what the purpose of the research project in general (and the interview specifically) was, how we would ensure confidentiality of the data, and what people could do in case they wanted to raise a complaint. Following this, we allowed people to ask any questions or raise any concerns. If people were happy, we proceeded to ask for verbal consent to partake in the interview. We considered verbal consent appropriate due to the high levels of illiteracy in Ohu.

Interviews were open in format to allow participants to tell their own stories about their photos. Discussions covered what was photographed, what role the item played in the life of the participant's clan, how the item had changed and may change over time, and what people were doing to adapt and respond to these changes. At the end of the interview, we specifically asked participants whether there was anything that they wanted to photograph but were unable to, and whether they had any questions about the project so far. We also asked all participants if their photos could be used for analyses and publication. It was made clear to participants that their data would only be used for scientific purposes, and would not be sold on to any other people or companies. The research team also highlighted its intention to bring back copies of the outputs to Ohu. We specifically allowed time for participants to question us on these statements, as there are cases in which scientists have been suspected by local communities not to have shared the financial benefits of a research project fairly with them (West, 2006), and we wanted to avoid confusion or misunderstanding as much as possible. After the explanations and answering participants' questions, all participants gave their oral approval for the use of their photos and interviews.

Interviews were conducted in Tok Pisin, a language commonly spoken in PNG and by all members of the research team involved in data collection, and recorded with the permission of participants. The local language in Ohu people is called Amele, yet most people in Ohu feel they can express themselves as well in Tok Pisin as in Amele. This is common for coastal villages close to Madang town. Given that the research team spoke Tok Pisin but not Amele, it was deemed appropriate to conduct the interviews in Tok Pisin. For all interviews, we liaised with community leaders in Ohu to ensure they and their clan members were happy for us to conduct the interviews. The leaders were on stand-by when we conducted the interviews. Where necessary, they helped translate from Tok Pisin to Amele and vice versa, although there were only a couple of instances where this happened. So, we do not believe conducting the interviews in Tok Pisin limited our research and its findings.

On the third day, the same protocol was repeated but this time we asked people to photograph 'things on your land that were important to the lives of people in your clan when you were a child'. It was made clear to participants that they were allowed to photograph the same item as the day before if they felt that the item still plays an important role. On the fourth day, the prompt was changed to 'things on your land that you think will be important to the lives of people in your clan when today's young children have grown up'. Again, participants were allowed to photograph similar items to previous days. Emphasizing the present on the second day, the past on the third day and the future on the fourth day, allowed us to explore past, current and future natural resource use and social-ecological changes in depth. We chose to encourage participants to think about time in terms of generations rather than specific years, as this is the timescale on which important changes are happening (Pascoe et al., 2019) and the goals of *Vision 2050* will be realised.

On the final day, we organised focus groups to discuss the photos in a group setting. We conducted the groups with men and women separately, because in Ohu the society has a patrilineal structure with men being seen as the decision-makers (Baynes et al., 2017), making it more difficult for women to speak out when men are present. We did, however, mix the age groups so younger and older people could hear each other's perspectives. Focus groups were held at the village's main meeting place as it was a convenient location to the participants. Discussions were led by the research team, and conducted in Tok Pisin. At the start of the focus group, each participant got the opportunity, if they wanted, to present his or her most important photos to the group and elaborate on the story behind the photo. We then discussed as a group the most important changes that were being highlighted based on the photos people presented. Next, we asked the group about adaptation measures that people have put, or are putting, in place, and what future measures may involve. Finally, we asked the group about how the future of Ohu and its WIAD Conservation area may look. Similar to the one-on-one interviews, the discussion was relatively open in format to allow participants to discuss what they thought was most useful.

At the end of the data collection, interviewees received printed copies of their photos. They were also given a small monetary payment to compensate for their time and effort, following community leaders' advice and NGBRC guidelines. Some argue that monetary incentives may compromise free, prior and informed consent (Goodman et al., 2004). However, the work for this project took up multiple days so only providing food and drinks would not have been an appropriate compensation for people's time. Also, payments were seen as a compensation for being 'part of the project' rather than payment for the interviews alone. Often a public-facing output is produced at the end of a participatory photography project with the intention of reaching a larger audience (Jenkins & Boudewijn, 2020). This was not done in our case, to avoid creating tensions between groups.

2.4 Thematic analyses

Data from participatory photography are rich, reflecting the multiple levels of analysis, including: (1) content of the photo (i.e. what is represented in the photo?), (2) the participant's interpretation of the photo (i.e. what is the story behind the photo?) and (3) assessment of differences by the researchers (i.e. is there a difference in photos taken and their interpretations between different groups?) (Gotschi et al., 2009). A hybrid approach that examines the different levels using theory-driven deductive techniques and data-informed inductive techniques is most likely to gain a holistic understanding of the data.

To analyse the content of the photos we used a deductive method, meaning that we grounded ourselves in existing theoretical frameworks (Braun & Clarke, 2006). When describing the content of the photos, participants often highlighted two aspects: first, what resource they had photographed, and second how the item contributed to their daily life. Resources were conceptualised as natural, human, social, financial and physical capitals, following the sustainable rural livelihoods approach (Carney, 1998; Scoones, 1998) (Appendix, Table 2). Other frameworks to conceptualise resources are available too, such as the Community Capitals Framework which recognizes the political and cultural dimensions of resources (Flora et al., 2004). However, the rural sustainable livelihoods approach best

fitted the aim of our analysis and the local context (Gutierrez-Montes et al., 2009). We classified each resource into one of these capital categories (Appendix, Table 3). Some resources could be classified into multiple categories. For example, in PNG pigs are often used for economic transactions and could thus be marked as both natural and financial capital (Sillitoe, 1999). We based the final classification of a resource by looking at which definition matched the resource most closely. In the case of pigs, this would be natural capital, for example.

Next, we captured the multiple uses of a resource in day-to-day life. When describing how the item contributed to their daily life, participants highlighted the positive and negative contributions of the resource. These descriptions were classified using Narayan et al.'s (2000) framework of well-being and ill-being. Based on research across 23 countries Narayan et al. (2000) identified that having sufficient material assets, health, social relations, security, and freedom of choice and action contributed to well-being. Dimensions of ill-being were often the opposites of well-being dimensions, with material lack, poor health, bad social relations, insecurity and powerlessness contributing to a 'bad life' (Appendix, Table 4). For an overview of which descriptions were classified into which category of well-being or ill-being, see Appendix, Table 5.

To analyse the story behind the photo, we used an inductive method. In an inductive analysis, in contrast to a deductive one, codes are created after carefully reading the text and identifying which themes and patterns emerge, allowing for novel and unexpected themes to arise (Braun & Clarke, 2006). In our case, the story of the photo was about how the photographed resource had changed and is changing, what causes these shifts and how people have adapted or are responding. Since these stories are highly localised it would have been inappropriate to use an existing framework. We listened to the interviews multiple times and noted down the main changes, drivers of change, and adaptations that people were mentioning. We then created corresponding codes, which allowed us to group the descriptions. For example, the quote 'Land will be short because of population growth. Some people will go to school and get a job so that they can earn money' was coded as 'the land is becoming short' (describing a change that is happening in Ohu), 'the population is increasing' (describing a driver of

the change) and ‘education is becoming more important’ (describing an adaptation strategy). For a full list of codes that emerged, see Appendix, Table 6.

To assess differences between time periods (past, present and future) and social groups (younger vs. older people, and men vs. women) we used statistical analyses. To assess whether capital and well/ill-being components had changed from the past to now, we conducted Fisher’s exact tests on the discrete quantities within the different categories of capital and well/ill-being. If there was a significant overall change, we used row-wise post-hoc tests with a Bonferroni correction to identify which capital or well/ill-being component had changed significantly. We repeated this procedure to determine changes from now to the future. To assess differences between groups we first split the data by time category. We then conducted Fisher’s exact tests and post-hoc tests for younger vs. older people and women vs. men for each time category separately. All statistical analyses were done in R version 4.0 (R Core Team, 2020). To conduct the Fisher’s exact test and the post-hoc test we used the functions ‘fisher_test’ and ‘row_wise_fisher_test’ from the rstatix package (Kassambara, 2020).

Results from the focus groups discussions were analysed by carefully reading the transcripts of the interviews and drawing out the main themes.

3. Results

A total of 360 photos were taken. All of the interviewees indicated that they photographed what they wanted to.

3.1 Capitals and well/ill-being

Out of the five capitals, natural capital was photographed most often, followed by physical capital, and then social and financial capital. The prominence of different types of capitals changed significantly depending on the time period people were asked to think about (Table 1, and Appendix Table 7), but there were no significant differences between demographic groups (younger vs. older, and men vs. women) in the capitals that they highlighted (Appendix, Table 8, Fig. 1 and Fig. 2). Of the different components of well- and ill-being, 'basic materials for a good life' was mentioned most frequently, followed by 'freedom of choice and action' and 'good social relations'. Similar to capitals, the prominence of the different components of well- and ill-being changed significantly over time (Appendix, Table 7), but there were again no significant differences between demographic groups for any of the individual components of well- and ill-being (Appendix, Table 8, Fig. 1 and Fig. 2).

Table 1: Capitals photographed by participants which they thought were important when they were young (left), are important now (middle) and will be important for their children (future). Note that human capitals were not photographed because we specifically asked participants not to photograph people. N = 360 photos.

Capital	Past	Now	Future	Total
Natural	94	109	40	243
Human	0	0	0	0
Social	2	1	19	22
Physical	24	7	42	73
Financial	0	3	19	22

In the past natural capital provided people with the basic materials to live a good life (Fig. 2). For food, families relied on crops in their gardens such as bananas and coconut, and plants in the forest such as tulip and sago (Fig. 3A). People also used coconut and sago, together with bamboo, to build houses. To earn money, individuals would mainly sell crops including banana, coconut, sago and tulip. Since access to health care services was limited, people relied on their natural resources for traditional medicines. For example, banana and papaya were used to relieve pain and sickness. However, some plants such as bamboo also caused harm by cutting people, and in that way contributed to ill-being. Lastly, natural capital played an important role in maintaining good social relations. In particular, pigs, bananas, coconut and tulip played a crucial role as important contributions to weddings and funerals (Fig. 3A). Pigs, however, could also cause trouble by disturbing people's gardens. Physical capital such as pig teeth and grass skirts was also important for customary practices such as *singsings* (traditional dances). Tools aided families in their work, although they, like bamboo, also contributed to poor health as tools could cut you if not handled properly (Fig. 3A).

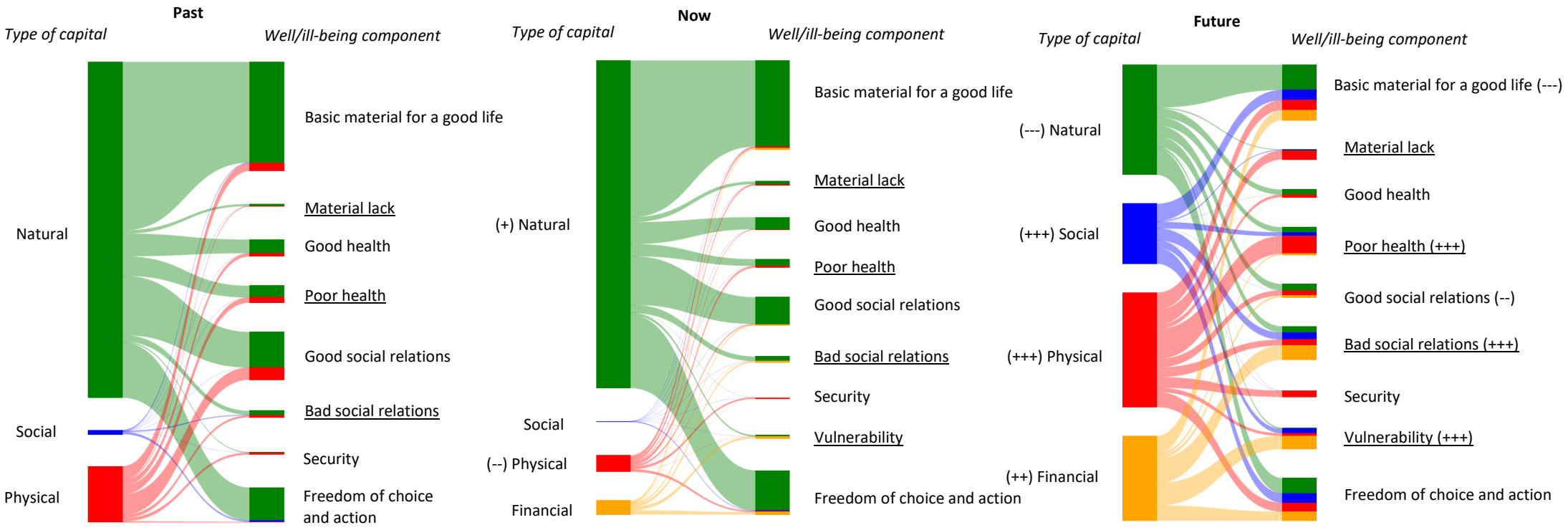


Figure 2: Type of capital and their contributions to the different component of well- and ill-being as highlighted by interviewees in the past (left), present (middle) and future (right). The types of capital that were that were highlighted in the interviews included natural, social, physical and financial capital. Well-being components included 'basic material for a good life', 'good health', 'good social relations', 'security' and 'freedom of choice and action' and are not underlined, whereas the ill-being component included 'material lack', 'poor health', 'bad social relations' and 'vulnerability' and are underlined. Overall counts of capitals and well/ill-being components determine the width of a bar. Model results of the row-wise post-hoc test with a Bonferroni correction are included with + indicating a significant increase and - a significant decrease in the count of the specified capital or well/ill-being component between time-periods. +/- = $p < 0.05$; ++/-- = $p < 0.01$; +++/--- = $p < 0.001$. For full results, see Appendix, Table 7 and 8. This figure was created using the R package 'bipartiteD3' (Terry, 2019).

At the moment, people still rely heavily on natural capital in their daily lives (Fig. 2). Land was often photographed, with many participants remarking that land is the basis for their lives (Fig. 3B). Bananas, coconut, sago and tulip are still widely consumed. A crop that has gained prominence for food is Chinese taro (Fig. 3B), which was introduced to PNG after 1870 (Bourke & Harwood, 2009). Chinese taro is now also used in customary practices. Pigs, however, are less often kept and used for customary purposes compared to the past, as Ohu community has introduced rules to limit the risk of pigs disturbing farms, consequently making pig rearing more cumbersome. People still rely on coconut and sago to build their houses. However, this is becoming more difficult as many coconut trees are now sick and the number of sago plants is declining because people still harvest sago but plant it less often. Coconut and banana are still being sold, but unlike in the past individuals now also sell betel nut and cacao (Fig. 3B). Betel nut is also consumed by local people themselves as a recreational stimulant, and it is customary to exchange betel nut with friends and family. Compared to the past, families invest more time and effort in growing and selling cash crops. With respect to physical capital, participants no longer highlight tools and traditional items, indicating that these items play a smaller role nowadays. Instead, interviewees say that their house, cars, cacao fermentary and modern (cotton) clothes are important. Financial capital also made its entrance when discussing the present, with a few people highlighting that money is an important resource nowadays.

In the future participants expect natural capital such as land and water to still be important, but less so than before. Interviewees expect clans to move away from relying on natural capital for their food and finding shelter. Instead, they will use money to buy food such as rice, vegetables and canned fish, and building materials for their houses such as corrugated roofing (Fig. 3C). Store-bought foods are easy to cook, participants remarked, although they also say that these foods are not very healthy and that the packaging can get into the environment if people do not dispose of the waste properly. People are excited to start living in modern houses as they last for a long time, although it was remarked that corrugated roofing can make the house feel hot and hurt you if a house collapses. Interviewees also highlighted that money may be used to buy alcohol and weapons, which could lead

to more fights and divorces, and worsening social relations. To earn money, participants expect people to have to go to school to gain the necessary knowledge to get a job or set up small businesses, which can include running a small store or selling poultry (Fig. 3C). Some interviewees pointed out that if individuals fail to get money they may revert to stealing or prostitution, which would lead to more community problems and increase people's vulnerability. Participants expected the next generation to be less concerned with maintaining past and present customs. If exchanges still happen, interviewees think that money and store-bought foods will be used rather than homegrown foods. On the other hand, modern tools such as mobile phones may help people to stay connected and improve social relations.

A

Banana – Participant 3 (woman, < 40 years)
'We used to sell bananas and earn money. We would eat bananas. And we would use them for customary purposes. If someone had died we would get bananas and bring it to the funeral. Or we would give bananas to our friends.'

Pig – Participant 24 (man, < 40 years)
'Before, we used to eat pigs and we used them for customary purposes. We would also sell them. Or if people didn't want to eat the pig themselves they would trade it with other people.'

Axe – Participant 11 (woman, > 40 years)
'When the axe worked, we could eat. We used it to make our garden and to plant crops which then provided us with food.'

B

Land – Participant 19 (woman, < 40 years)
'Land is useful for building a house, for growing food, for planting fruits and for many other things.'

Chinese taro – Participant 13 (man, > 40 years)
'When I was young Chinese taro wasn't popular. Taro, yes, taro was popular. Now taro is starting to disappear and Chinese taro is becoming popular and is taking over taro's work.'

Betel nut – Participant 19 (woman, < 40 years)
'Now many people plant betel nut. Before only few people planted betel nut. People thought that it was a useless tree. But now we earn money with betel nut.'

C

Modern house – Participant 12 (woman, < 40 years)
'Now we use materials from the forest to build our house. In the future these materials,

Money – Participant 7 (man, > 40 years)

'In the future people will not build their house, people will

Shop – Participant 23 (man, < 40 years)

'I think that in the future people who can't find a job will run an

including sago leaves, will no longer be available and we will depend on corrugated roofing to build our house.'	not make food gardens. Money will buy a house, money will buy food. People will depend on money.'	informal business so they can sustain their livelihoods. It will allow them to earn money.'

Figure 3: Pictures and accompanying quotes portraying capitals in the past (A), present (B) and future (C).

3.2 Changes, their drivers and adaptations

Life in Ohu has changed and is still changing due to the influence of different drivers. Participants are noticing that, compared to the past, many of their crops and animals have become sicker in the last couple of years. Traditionally important crops such as bananas and coconuts are now displaying symptoms with their leaves turning yellow and withering, and cacao is also not doing well (Fig. 4A). Some interviewees think that crops get sick because insects attack them. Others link it to changes in the weather. Related to this, many people complain that the yields from their gardens are declining; in particular banana and taro no longer grow well. Part of this is felt to be a direct result of the increase in crop diseases, but many also remark that it is a result of declines in soil fertility. Participants say that they now only have small areas of land to work because of an increase in the number of people living in Ohu. This is forcing them to use their land and soils more intensively, causing yields to decline (Fig. 4A). Land shortages are also causing more disputes between different families about who owns what land, and who can make use of it. The increase in population and in the number of gardens and cash crop blocks has caused a lot of forest to be cut (Fig. 4A). The loss in big trees is, in turn, negatively affecting water flows in Ohu, according to interviewees, with streams being smaller, less cold and tasting sour nowadays.

To deal with the changing situation, farmers have started to plant different crop species. For example, farmers now often grow Chinese taro instead of taro, and betel nut instead of coconut and cacao. However, betel nut is now also sometimes getting sick and displaying similar symptoms to banana plants and coconut palms. This is causing some farmers to shift again, and they are starting to

grow vanilla (Fig. 4B). Peoples also continue to shift away from relying on natural resources. For example, instead of using tulip trees to make traditional bags called *bilums*, women use string and wool, and people are starting to buy food from supermarkets (Fig. 4B). Families are also becoming more concerned with sending their children to school, so they have alternative ways of making a living (Fig. 4B). Participants frequently mentioned that it can be challenging to pay for the school fees, especially when children continue to secondary and tertiary education. When discussing this in the focus groups, participants often highlighted the importance of working together as a family and a clan to find the necessary money and resources to support a child's education.

A

Cacao fermentary – Participant 18 (woman, > 40 years)
'Climate change came and is destroying cacao. All my pods are now spoiled. Now we are all no longer cleaning our cacao trees. We stopped doing that now. The pipe of the cacao fermentary also broke.'

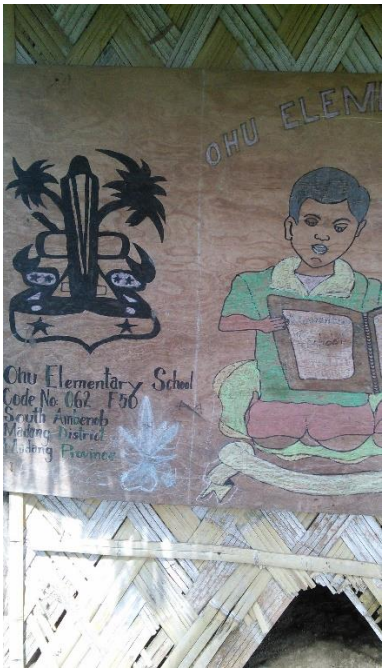
Sweet potato – Participant 14 (man, < 40 years)
'When I was young, we had enough land and the soil was rich. So we used to harvest quite big crops. But now we keep using the same land for our garden. You can't move because other family members will be there because the population is growing. So now crops like sweet potato are small.'

Forest – Participant 7 (man, > 40 years)
'We cut the big forest just to make gardens. Now all the birds, cassowaries and wallabies have disappeared. Maybe the fire killed them all.'

B

Vanilla – Participant 12 (woman, < 40 years)
'Now we are starting to plant vanilla.'

Bilum – Participant 19 (woman, < 40 years)
'Before people used bilums made from tulip. But nowadays we make bilums from string.'



School – Participant 23 (man, < 40 years)
'In the past many people didn't understand the importance of education and they didn't send their children to school. The school was there, though. But now many of us are realising how important education is and we bring our children to school.'

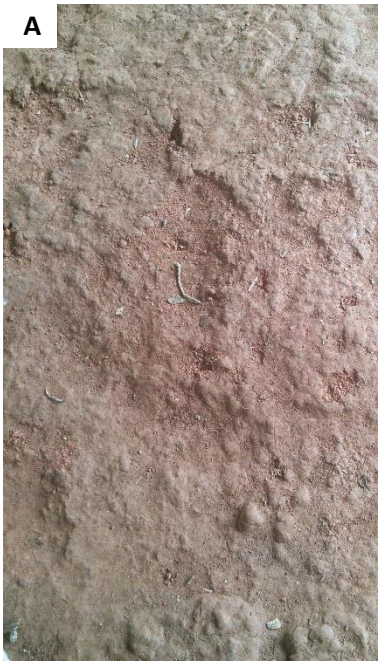
Figure 4: Pictures and accompanying quotes portraying how life changed from the past to now (A), and how local community members have adapted to the changes so far (B).

Going forward, people anticipate that natural resources, including betel nut, tulip, banana, coconut, pigs, sago, Chinese taro and water, will still be available. However, they do expect many of them, including coconut, sago and banana, to decrease in abundance as a result of disease in the case of coconut and banana, and over-harvesting of sago. Participants also expect the population to continue to grow, which will result in land becoming even scarcer. Some are predicting that Ohu will further develop, and that in the future the village will host a big modern aid post, will be connected to power and dam the water (Fig. 5A). A few interviewees are wondering whether mining companies will show interest in their land and resources. Some expect potential mining projects to yield money

and help develop the area by building schools and hospitals, but it is also said that mining would destroy their land, water and resources.

Some participants pointed out that the decrease in natural resources may encourage people to start conserving them. People in Ohu have already made a start with this by setting up their locally-owned WIAD Conservation project, and many participants are keen for this project to continue (Fig. 5B). Nevertheless, interviewees are foreseeing shortages in natural resources and thus they are pushing their children to go to school. They hope that by going to school, children can gain the necessary knowledge to either look after their land well and keep selling cash crops, or to find a job and get paid a wage (Fig. 5B). Earning money will allow them to shift away from relying on food gardens and forests, and instead they can buy food in the supermarket and materials in the store. When discussing the future and education in the focus groups, participants pointed out that it will be necessary for them to build their own schools rather than to 'wait for the government'. They also highlighted that it is important that clan members who manage to get an education return to the community to help teach the next generation. Participants expected the changes in livelihoods to cause people to become more independent and less concerned with maintaining traditional customary knowledge and relationships (Fig. 5B).

A

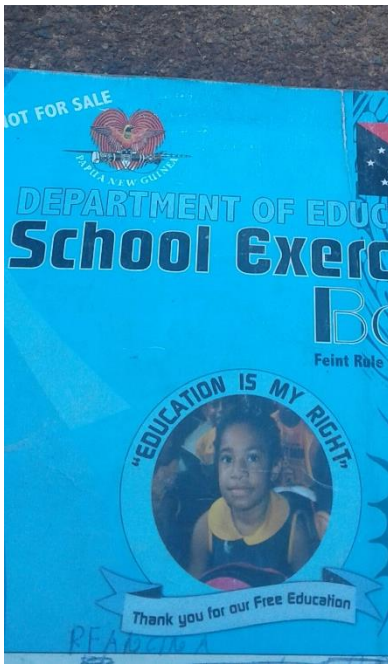


Land – Participant 23 (man, < 40 years)
'We use land to make gardens, to build houses and to plant cash crops. I think that the next generation will not plant anything. Instead they will use the land to build buildings and development will come.'

Aid post – Participant 14 (man, < 40 years)
'In the future when there is no more land because of development and the population is big, it will be difficult to find any bush medicines, so we will need to get medicines from the aid post.'

Generator – Participant 12 (woman, < 40 years)
'Now we use small torches to get light. I don't think this will be the case in the future. Modern technology is reaching us now. We will start using electricity soon.'

B



Conservation – Participant 8 (man, < 40 years) 'When we brothers hold each other's hands things will change for the conservation area. We will no longer destroy the trees. The conservation area will expand. All trees will grow again. The forest will thrive.'	School – Participant 15 (man, < 40 years) 'Now our lives depend on our gardens. But in the future there will be no more gardens, because the population will increase. Our children will need to go to school and they will depend on their knowledge for their survival. School will be to them what gardens are to us today.'[1]	Store food – Participant 7 (man, > 40 years) 'Now we use rice and canned fish for our customs. We buy a bag of rice or a bale of rice, and we buy half a carton or a full carton of canned fish and we will use it for making custom. But this will change again, because now many are feeling that it is too expensive to make custom.'

Figure 5: Pictures and accompanying quotes portraying how life is likely to change within the lifetime of the next generation (A) and how local community members think their children will adapt to current social-ecological changes (B).

3.3 A diversity or unity of views?

Within a community, perspectives may differ or converge. It is important to explore how widespread and (un)contested views are, as this produces a better understanding of what may work for which groups.

As highlighted above, we did not find statistical differences between younger vs. older people and men vs. women in the type of capitals that they highlighted and the components of well- and ill-being described. However, different demographic groups may still experience social-ecological changes differently and it is important to recognise where views diverge (Aregu et al., 2016). Given the relatively small sample size in our research we need to be careful when highlighting any differences as they may not be representative to the demographic group as a whole. However, we still want to illustrate how lived experiences may differ, keeping the caveat of our small sample size in mind. In our research, for example, both younger and older people spoke about the fact that education is becoming more important in people's daily lives. Some older people expressed their concerns over the fact that those who go to school may no longer know how to make gardens or build houses. Some

[1] The photo was taken by a different participant (participant 8). The photo participant 15 took included school children. To protect their anonymity, we replaced that photo with this one. Both photos represent school.

younger people, on the other hand, said that older people may not recognise the importance of education as they are too focused on more traditional lifestyles. So both groups recognised the role of education going forward, but they may diverge in how much emphasis should be placed on formal education versus learning skills related to a more traditional lifestyle.

Similarly, men and women highlighted similar capitals and components of well- and ill-being. However, this does not mean that there are no differences in their lived experiences or viewpoints. For example, even though both men and women highlighted the importance of natural capitals in their daily lives, women tended to focus more on crops grown in the gardens (such as banana and Chinese taro) whereas men focused more in crops grown in blocks (such as coconut and cacao). Traditionally, women in PNG are in charge of looking after gardens, whereas men are more concerned with cash crops (Eves et al., 2018). So even though both groups recognised the importance of natural capitals in their daily life, they may differ in their opinions on what crops deserve more attention and care.

Besides differences between demographic groups, it is important to understand potential differences within and between clan groups. During the focus group discussions, we found that for the most part people agreed with each other's analyses. Also between focus groups (and thus clan groups) there was consistency in how people viewed the future. All groups marked land, food gardens and cash crops as their most important resources, population growth as the main driver of change affecting their resources, and education as key to their children's future. However, there were two important points on which groups differed. Firstly, the four focus groups containing participants closely involved in the management of WIAD Conservation highlighted that WIAD Conservation plays an important role in community development by bringing in education, cash and resources. The two focus groups whose participants were not directly involved in WIAD Conservation still saw it as an important asset, but argued that the community also needed additional projects such as a livestock-rearing project. The other contested point between and within focus groups was about the role that companies, including mining companies, would play in the future. Some predicted that companies will

show interest in Ohu's resources and try to establish a project within the community. This would bring benefits, according to respondents, such as easy access to cash, but would also have negative consequences as land may be destroyed and water polluted. Others did not think so much about external companies and highlighted the importance of cash cropping and small business projects going forward.

4. Discussion

The participatory photography process yielded rich visual data and stories, which explored local perspectives on natural resources, social-ecological changes and adaptation strategies.

4.1 Insights from using participatory photography in Ohu

Results from the participatory photography project triangulated and expanded current scientific knowledge on social-ecological changes that are happening in PNG. Previous research on environmental change by Gurr et al. (2016) describes the increasing presence in PNG of Bogia coconut syndrome and banana wilt associated with phytoplasma, which causes coconut palms, banana plants, betel nut palms and taro to become diseased. Based on their photos, participants also highlighted that many of their crops, and especially coconut and banana, are dying due to disease. Similarly, Fujinuma et al. (2018) describe how land use intensification is causing declines in soil fertility, Shearman et al. (2009) call attention to the negative impacts of smallholder farming on forest cover in PNG, Schmidt, Mueller and Rosenbach (2020) outline how people's diets change when they engage in off-farm work, and the World Bank (2020) shows the rapid increase in PNG's population, all of which are also highlighted by our participants. In their stories participants also focussed on the intricate interplay between all of the changes that are happening and their ultimate drivers. For example, when discussing crops, participants often went on to say that they attributed the increase in crop diseases

to more frequent insect attacks and changes in the weather. These changes were, in turn, connected to the loss of local forest, which people attributed to a rapidly growing population, because more people needed to cut trees to make food gardens. Similarly, people related the decreases in soil fertility to land shortages, which again they attributed to a growing population. Ultimately, participants highlighted population growth as the main driver of change in their community.

People attributed most of the changes that they were observing to things that were happening in their own community, rather than placing the attribution for these drivers with external actors. This is similar to Pascoe et al.'s (2019) description of discussions of the causes of climate change with communities in Milne Bay Province of PNG. This focus on local drivers of negative environmental changes may reflect deeper conceptualisations of the relationship between people and the environment, and the scale at which change is generated and felt in PNG. It also differs from the conceptualisation of causality that external actors (such as researchers) may have. Understanding local perspectives on the importance and interconnectedness of changes and their drivers enriches scientific knowledge. It is also vital for better understanding which changes and drivers community members perceive as most significant and feel they have agency over, and may thus be keen to address (Bennett & Dearden, 2013).

The photo project also helped to shine light on the perceived consequences, both positive and negative, of social-ecological changes. Due to an increase in crop diseases, a decrease in soil fertility and forest loss, people are expecting to have to shift from relying mainly on natural capital to relying on a combination of natural, physical, social and financial capitals. If people succeed, participants point out that this may allow their children to increase their living standards. For example, they will have the necessary money to buy the materials to build a high-quality house. However, interviewees also point out that moving away from natural capital may worsen social relationships if people use money to buy alcohol and weapons, and may increase people's vulnerability to stealing or prostitution. Identifying both vulnerabilities and opportunities, and acknowledging uncertainties is crucial when

designing adaptation plans, as this may help in recognising and mitigating unintended consequences and allow positive opportunities to be nurtured (Masterson et al., 2018).

Participants sought holistic adaptation strategies. For example, when people noticed a decrease in the abundance of birds of paradise, they linked this to a decrease in forest. They subsequently decided to preserve the remaining primary forest, which formed the basis for WIAD Conservation. Going forward, people expect other resources (such as sago) to further decrease, and they again highlighted the importance of conservation. How exactly to achieve conservation of resources while also accommodating a larger population may be difficult. One solution people in Ohu offered was to increase educational opportunities, which would allow them to kill two birds with one stone: It would help them to better manage their land as well as increase their chances of finding employment, earning money and buying items, allowing them to rely less on their direct environment.

However, implementing adaptation strategies can be difficult, and in certain cases this can cause communities to make complex decisions. For example, there is currently one elementary school and one primary school in Ohu where students can complete grade 1 to 8, while for secondary schooling students need to go further afield and either travel extensively on a daily basis or attend a boarding school. Theoretically, until 2019 schooling up to grade 10 was cost-free, as the government subsidised students' tuition fees (*Implementation of 2012 Tuition Fee Free Education and Tuition Fee Subsidy Policy*, 2012), although often families still had to pay 'project fees'. In December 2019, the PNG government replaced their Tuition Fee Free policy with a Government Tuition Fee Subsidy, which involves families paying 37% of tuition fees (*The Government Tuition Fee Subsidy Policy to Make Education a Shared Responsibility*, 2019). So in practice attending school in PNG has not been cost-free, and families often struggle to pay, as also highlighted by our participants. So far, people are relying on their cash crops to pay for school fees, and participants pointed to the importance of good cash crop management going forward. However, organisations or companies which offer to provide education or other development services are often warmly welcomed (Novotny, 2010; Soukup, 2012). At the time of research, there were ongoing debates within Ohu about whether a mining company

should be allowed to enter the village. These discussions are not new, though, as already in the early 1990s a gold mining company had approached Ohu and undertaken scoping work. Eventually the mining did not go ahead as people feared that mining may destroy their land and pollute their water, resources that they currently rely heavily on. However, some are attracted by the idea of mining allowing them fast access to cash. These results show that people in Ohu, like many other communities, sometimes feel that they need to make trade-offs between conserving their land and forest, and realising community development (Jacobs et al., 2020).

Interventions that seek to overcome the apparent tension between conservation of resources and people's priorities for development, such as access to education in Ohu's case, would be beneficial. Some clans in Ohu have made a start with this themselves by no longer using WIAD Conservation only to preserve the bird of paradise, but also as a means to attract (international) researchers to conduct fieldwork, bringing economic benefits, employment possibilities and educational opportunities (Weiblen & Moe, 2016). Other examples of initiatives that aim to bridge conservation with community development across PNG include a royalty payment scheme for the conservation of 10,000 ha of forest in Wanang (Novotny, 2010), the SURFACES project which works to integrate biodiversity conservation with improved access to health care (Middleton et al., 2020), and the offering of a premium price for coffee grown by landowners of the YUS Conservation Area (Beehler & Kirkman, 2013). However, these programmes are not without challenges; for example sometimes local actors perceive the benefits as not sufficient or raise concerns about how the benefits are shared among different stakeholders (Henning, 2015; Soukup, 2012; West, 2006).

Our findings have implications for future research and government planning in PNG. Currently, PNG's *Vision 2050* acknowledges that agricultural research is important for the country's development, but does not mention specific areas of interest. Crop disease and land shortages were highlighted by our participants as two key issues affecting current and future livelihoods. We recommend that research and government institutions focus part of their work around these two themes. Further implementation of projects that aim to bridge conservation with community

development, and evaluation to learn lessons and support scale-up, would also be beneficial (Beehler & Kirkman, 2013; Benson, 2012; Henning, 2015; Novotny, 2010; West & Kale, 2015). Finally, our participants highlighted the importance of their clans and tribes working together so they can realise the desired development, such as building a school, setting-up a livestock project or improving the conservation area, without having to rely on outside organisations. However, currently families, clans and tribes are often divided (Baynes et al., 2017). *Vision 2050* acknowledges this and highlights the importance of resolving law-and-order issues around the country (National Strategic Plan Taskforce, 2011). However, our participants believed that it is important to go beyond quelling tensions to also build trust within and between groups. Certain programmes, such as the Family Farm Team programme (Pamphilon, 2019), are already exploring how groups of people in PNG can be brought together to work effectively, and further exploration of this approach would be of great value.

4.2 The participatory photography method

The participants in this project overall expressed their enjoyment of the process of taking photographs and stated that it allowed them to select which aspects of their lives were most important to their clans, similar to Masterson et al.'s (2018) findings. People expressed their hopes and fears during the project, demonstrating that participatory photography can be a useful method to understand both positive and negative consequences of changes, as also highlighted by Bennett and Daerden (2013). Finally, the method encouraged community dialogue about the future as it brought families together, provided a space for both men and women to talk about the future, and caused people to highlight the importance of teamwork within their clan. This shows that participatory photography can stimulate self-determination and benefit the community beyond just the production of knowledge, as also argued by Jenkins and Boudewijn (2020).

Despite the many insights that the participatory photography process engendered, we did encounter some methodological limitations which future research could aim to improve. First,

participatory photography relies on items having to be photographed at a given point in time, which may have limited people's ability to communicate their experience of the past and their vision for the future (Lopez et al., 2018). To overcome this, future research could combine participatory photography with additional arts-based methods such as CreativeVoice which allows for less reliance on currently-present items (Lopez et al., 2018; Soukup, 2012). Second, we explicitly asked participants not to photograph any people as we could not guarantee that people in the photo would have given permission for the photo to be taken. This meant that we did not capture human capital. Since our main area of interest was natural resources, we do not believe this negatively affected the results in our study. However, if it would be of interest to include human capital, multi-year studies would allow the time needed to properly request permissions to be photographed. Finally, to analyse the content of a photo and the use of an object, we used existing frameworks. Even though these frameworks are useful to summarise and standardise results, they have their limits as well. For example, in some cases they may hide differences in lived experiences between demographic groups. Combining deductive analyses with a description of where differences may be hidden, can overcome such limits and we have strived to do this here.

5. Conclusion

Using participatory photography, we explored local perspectives on natural resources, social-ecological changes and adaptation strategies. Our results provided an important triangulation for scientific studies and allowed the exploration of how different social and ecological changes interact. The process gave insights into participants' perceptions of the causes and consequences of these changes, highlighted adaptive strategies and the complexities of realising them, and provided suggestions for future research and planning processes. The photos told the story of how farmers in Ohu have made, and are still making, complex decisions about how to manage their resources and achieve development of their community in the face of rapid social-ecological changes. As one of the participants put it: ‘we need to decide: if you have a banana and a coin in your mouth, which one do you want to swallow?’.

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Data availability

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.

Declaration 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.

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Appendix

Table 1: Description of the sample.

		Group 1	Group 2	Group 3
Total number of people		8	8	8
Age	Younger (<40 years)	4	4	4
	Older (>40 years)	4	4	4
Gender (no. of ♀)	Men	4	4	4
	Women	4	4	4
Tribe - Clan (no. of people)		Tribe 1 - Clan 1: 8	Tribe 1 - Clan 2: 8	Tribe 2 - Clan 3: 1 Tribe 2 – Clan 4: 2 Tribe 2 – Clan 5: 3 Tribe 3 – Clan 6: 1 Tribe 3 – Clan 7: 1

Table 2: Overview of the five capitals and their definitions, used here to categorise the photographed items. Adapted from Scoones (1998) and Carney (1998).

Capital	Definition
Natural	Natural resource stocks (e.g. soil, water and air) and flows of energy and material that produce goods and services.
Human	The skills, knowledge, physical ability, motivation and health needed to pursue your livelihood.
Social	Social resources (e.g. schools, businesses and families) upon which people draw when pursuing their livelihood.
Physical	Materials goods and fixed assets (e.g. tools, roads and buildings) which are generated by applying human productive activities to natural capital, and which contribute to provide a flow of goods and services.
Financial	Capital base (e.g. shares, bonds and cash) which are needed for the pursuit of a livelihood. Unlike the other capitals it has no real value in itself, but it is representative of natural, human, social or physical capital.

Table 3: Overview of how each photographed resource was classified into the different categories of capitals, following Scoones (1998) and Carney (1998). Items in quotation marks indicate the Tok Pisin name used, as we were not aware of the common English name.

Item photographed	Classified as
Aibika	Natural capital
Aid post	Physical capital
Aila (*Inocarpus fagifera*)	Natural capital
Bamboo	Natural capital
Banana	Natural capital
Bandicoot trap	Physical capital
Bank card	Financial capital
Bean	Natural capital
Betel nut	Natural capital
Bible	Physical capital
Bilum	Physical capital
Boombox	Physical capital
Breadfruit	Natural capital
Cacao	Natural capital
Car	Physical capital
Cassava	Natural capital
Chicken	Natural capital
Coconut	Natural capital
Conservation project	Social capital
Cooking oil	Physical capital
Corn	Natural capital
Mustard	Natural capital
Drum	Physical capital
Fence	Physical capital
Fermentary	Physical capital
Fish pond	Natural capital
Forest	Natural capital
Garden	Natural capital
Garden food	Natural capital
Generator	Physical capital
House and kitchen	Physical capital
'Kanda' (*Flagellaria indica*)	Natural capital
'Kumu mosong' (*Ficus copiosa* Steud.)	Natural capital
Land	Natural capital
Malay apple tree	Natural capital
Mango	Natural capital
Mat	Physical capital
Mobile phone	Physical capital
Modern clothes	Physical capital
Pacific walnut (*Dracontomelon dao*)	Natural capital
Money	Financial capital
Okari nut	Natural capital
Palm species (*Hydriastele costata*)	Natural capital
Pandanus	Natural capital

Papaya	Natural capital
Pig	Natural capital
Pineapple	Natural capital
Pumpkin	Natural capital
Road	Physical capital
Sago	Natural capital
School	Social capital
Shop	Social capital
‘Sis’ (*Pengume edule*)	Natural capital
Solar panel and battery	Physical capital
Store food	Physical capital
Sweet potato	Natural capital
Taro	Natural capital
Chinese taro	Natural capital
Tomato	Natural capital
‘Ton’ (*Pometia pinnata*)	Natural capital
Tools	Physical capital
Traditional items	Physical capital
‘Tulip’ (*Gnetum gnemon* L.)	Natural capital
Vanilla	Natural capital
Water	Natural capital
Wooden utensils	Physical capital
Yam varieties	Natural capital

Table 4: Overview of the five components of well-being and their definitions, used here to categorise the described meaning of photographed items. Adapted from Narayan et al. (2000).

Well-being component	Definition	Ill-being component	Definition
Basic material for a good life	Includes having access to food year-round, having adequate resources to make a living, and being able to gain a livelihood.	Material lack	Includes a lack of food, not having adequate resources to sustain a living, and being uncertain about employment.
Good health	Includes having good physical health, being able to dress and appear well, and living in a healthy physical environment.	Poor health	Including experiencing hunger, pain or discomfort, and often being exhausted.
Good social relations	Includes being able to marry and take care of children, being able to have self-respect and dignity, and have peaceful and good relations within the family, community and country.	Bad social relations	Includes being excluded by others or finding it necessary to self-exclude, being rejected and feeling lonely.
Security	Includes living in a peaceful, predictable and secure place, having access to justice, having security and support in old age, and being able to look forward to the future with confidence.	Vulnerability	Includes being exposed to mishaps, stresses and risks in the physical environment, society, economy or legal system, and being defenceless against damaging loss.
Freedom of choice and action	Includes being able to help others, and having the ability to make choices and have some control over what happens next.	Powerlessness	Includes being unable to control what happens, the inability to plan for the future and the imperative of focusing on the present.

Table 5: Overview of how descriptions of the use of photographed resources were classified into the different categories well-being or ill-being, following Narayan *et al.* (2000).

Use of item	Classified as
Food	Basic material for a good life
Own consumption	Basic material for a good life
Drink	Basic material for a good life
Cook food	Basic material for a good life
Hunting	Basic material for a good life
Work tools	Basic material for a good life
Build house	Basic material for a good life
Use as bilum	Basic material for a good life
Firewood	Basic material for a good life
Make other assets	Basic material for a good life
Make farm	Basic material for a good life
Buy items	Basic material for a good life
Buy services	Freedom of choice and action
Storage	Basic material for a good life
Sell	Freedom of choice and action
Education	Freedom of choice and action
Job	Basic material for a good life
Provides services	Freedom of choice and action
Medicine	Good health
Harm health	Poor health
Harm assets	Material lack
Happiness	Good health
Clean	Good health
Social relations	Good social relations
Culture	Good social relations
Traditional dances	Good social relations
Safety	Security
Birth	Good health
Cover body	Good health
Fights	Bad social relations
Get drunk	Vulnerability
Marriage problems	Bad social relations
Steal	Vulnerability
Spoil environment	Poor health
Not work well	Poor health
Expensive	Material lack
Hard work	Material lack
Low yield	Material lack
Hot	Poor health
Communication	Good social relations
Transport	Basic material for a good life
Important for life	Basic material for a good life
Empower	Freedom of choice and action

Table 6: Codes that emerged from the interviews and describe the main changes affecting the photographed resources, the drivers of these changes and possible adaptation strategies.

Theme	Codes emerging from the interviews
Changes	We live a tougher life
	We live a better life
	The future depends on God
	Not sure how the future will look like
	It is becoming sick
	Yields are low
	We look after it more
	We look after it less
	We use it less on a daily basis
	We use it more on a daily basis
	This resource will continue to be present
	Money is becoming more important
	We use it less for customary purposes
	We use it more for customary purposes
	We make a small farm
	We make no farm
	The resource is becoming short
	The quality of the resource is low
	There are fewer animals
	We change the way we make fences
	We change our diet
	We change the house we live in
	We change our life pattern
	We change to using modern materials
	We change the technique we are using
	We sell this more often
	We are now selling it, whereas before we wouldn't
	We sell this less often
	The price is going up
	The price is going down
	We engage in less customary purposes
	We are losing traditional knowledge
	We are losing traditional items
	We have more knowledge
	We are using modern medicines
	Babies are born in hospitals
	Services are coming to our community
	Sago is declining
	There are more law-and-order problems
	We hunt less
	We are spoiling our environment
Reasons for changes	We make more farms
	The forest is being lost
	People changed their attitude and became lazy
	The land is becoming short
	Soil quality is low
	The species is being overhunted
	We now use chemicals

	Insects are attacking more often
	The climate is changing
	The population is increasing
Adaptation strategies	We plant different species
	We need to buy items
	We need to save the resource
	Education is becoming more important

Table 7: Outcomes of the Fisher's exact tests to determine whether capital and well/ill-being component changed over time. Row-wise post-hoc tests with Bonferroni correction are highlighted in grey were relevant.

		Time	
		Past to now	*Now to future*
Capital		p = 0.0015	p < 0.001
	Financial	p = 0.99	p = 0.0020
	Natural	p = 0.046	p < 0.001
	Physical	p = 0.0068	p < 0.001
	Social	p = 1	p < 0.001
Well/ill-being		p = 0.006	p < 0.001
	Basic material for a good life	p = 1	p < 0.001
	Material lack	p = 1	p = 0.38
	Good health	p = 1	p = 0.67
	Poor health	p = 0.82	p < 0.001
	Good social relations	p = 0.35	p = 0.0016
	Bad social relations	p = 1	p < 0.001
	Security	p = 1	p = 0.19
	Vulnerability	p = 0.16	p < 0.001
	Freedom of choice and action	p = 0.061	p = 1

Table 8: Outcomes of the Fisher's exact tests to determine whether capital and well/ill-being components differed between younger vs. older people and women vs. men in the past, now or future. Row-wise post-hoc tests with Bonferroni correction are highlighted in grey where relevant.

			Group	
			Age (Younger, n = 12; Older, n = 12)	*Gender (Men, n = 12; Women, n = 12)*
Capital	Past		p = 0.39	p = 0.45
		Financial		
		Natural		
		Physical		
		Social		
	Now		p = 1.0	p = 0.19
		Financial		
		Natural		
		Physical		
		Social		
	Future		p = 0.43	p = 0.90
		Financial		
		Natural		
		Physical		
		Social		
Well/ill-being	Past		p = 0.035	p = 0.049
		Basic material for a good life	p = 1	p = 0.47
		Material lack	p = 0.98	p = 0.45
		Good health	p = 1	p = 1
		Poor health	p = 1	p = 1
		Good social relations	p = 1	p = 1
		Bad social relations	p = 0.84	p = 1
		Security	p = 0.49	p = 1
		Vulnerability		
		Freedom of choice and action	p = 1	p = 0.45
	Now		p = 0.45	p = 0.74
		Basic material for a good life		
		Material lack		

	Good health		
	Poor health		
	Good social relations		
	Bad social relations		
	Security		
	Vulnerability		
	Freedom of choice and action		
Future		p = 0.50	p = 0.70
	Basic material for a good life		
	Material lack		
	Good health		
	Poor health		
	Good social relations		
	Bad social relations		
	Security		
	Vulnerability		
	Freedom of choice and action		

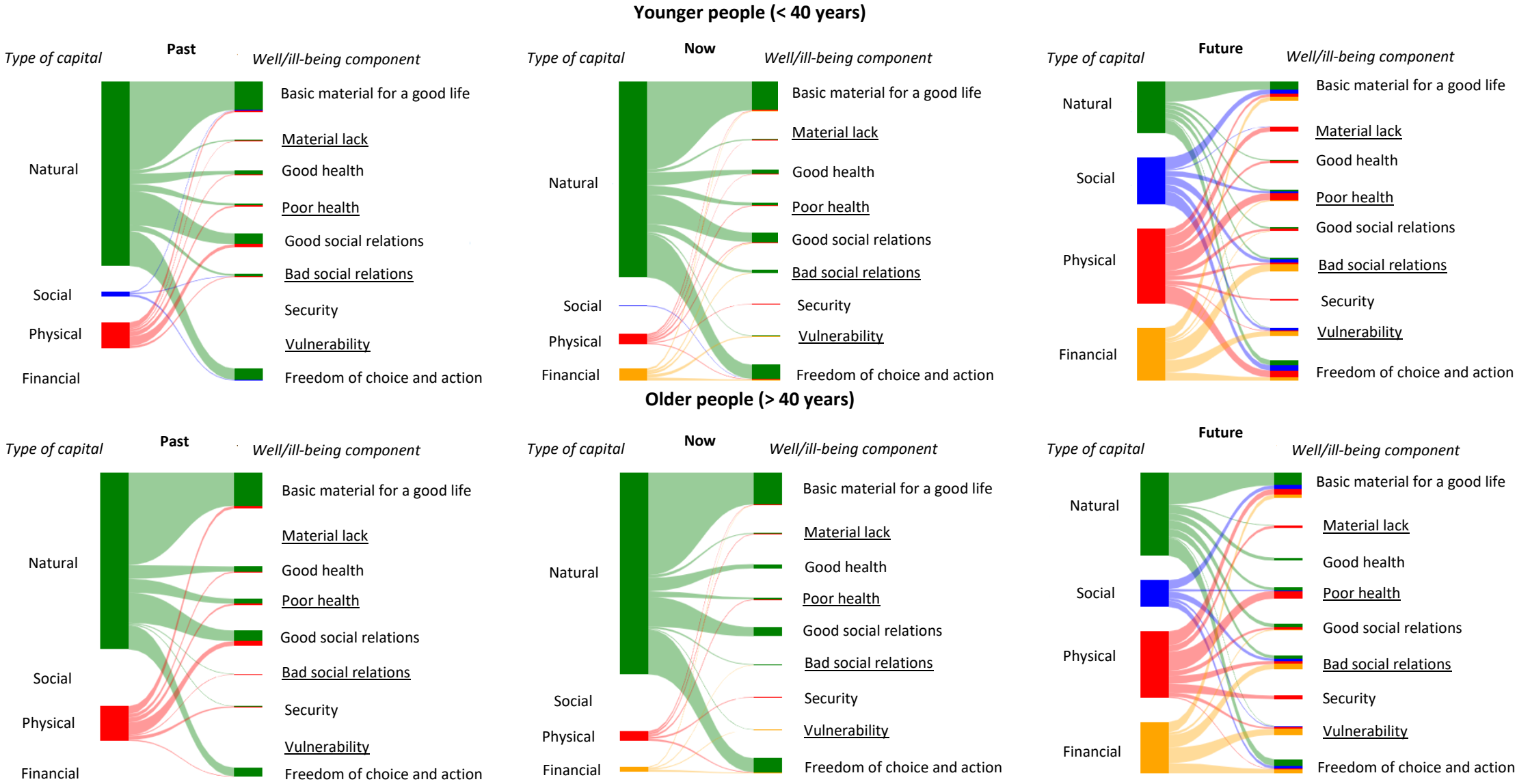

Figure 1: Type of capital and their contributions to the different component of well- and ill-being as highlighted by younger (top) and older (bottom) people.

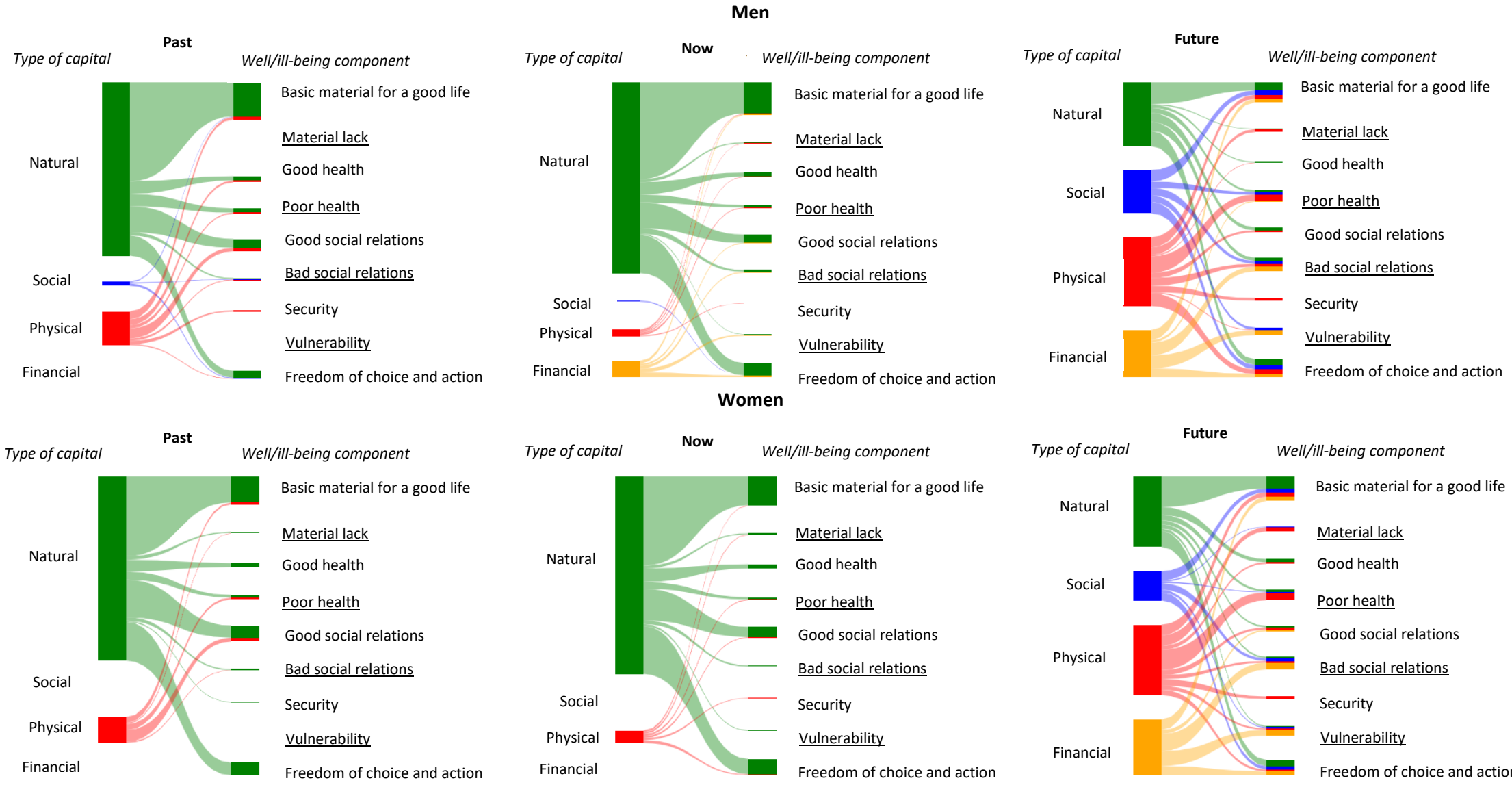

Figure 2: Type of capital and their contributions to the different component of well- and ill-being as highlighted by men (top) and women (bottom).