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The Succession of Farmers' Perceptions of Transitioning Landscapes – A Case Study of Agroforestry in the Middle Hills of Nepal

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Abstract
Out-migration from small-scale agricultural holdings in Nepal's middle hills is resulting in forest succession on abandoned land. Such early landscape transitions are often guided by policy to maintain a productivist path. However, farming households in rural Nepal are themselves transitioning from their dependence and attachment to the land. The walk and talk methodology was selected to follow up socioecological surveys with farmers in the middle hills to understand perceptions of forest succession on abandoned agricultural land. This participatory research methodology engages people in their own socio-ecological context – with farmers leading researchers along paths that advances dialogue over the course of the interview. Based on analysis of the discussions and observations of attitudes, perceptions of changing landuse and benefits associated with forest succession evolved with time since land abandonment. Early stage perceptions that focused on the loss of previously productive land developed over time to include attitudes of tolerance, acceptance and even commendation of the rewards gained from tree resources. The results infer that adaptation to the changing landscape is a continuous process that requires reflexive policies and supporting institutions that enable stages of adjustment during transition. Transition management that anticipates actors' concerns from the outset could assist transformation of agricultural landscapes and improve resilience in the socio-ecological system for sustainable livelihood outcomes. Opportunities within each stage of transition, which include the promotion of successional agroforestry systems, require different forms of support as farmers adapt their outlooks to alternative landscapes and livelihoods that can create resilience through diversity.

Keywords Transitioning landscapes · Land abandonment · Forest succession · Farmer perceptions · Nepal

Introduction

The landscape in the middle hills of Nepal is transitioning as forests encroach traditional, mosaic farming systems. The physical response to land abandonment – and consequent forest succession – is ultimately driven primarily by out-migration, which itself is a complex dynamic that intersects social, political, environmental and economic domains (Jaquet et al., 2015; Khanal & Watanabe, 2006; Paudel et al., 2020; Rai et al., 2019). Policy and multi-level governance in Nepal is attempting to address growing threats of food insecurity from decreased agricultural production by focussing on returning workers to the fields, increasing access to land via land banking or, in some municipalities, introducing penalites for leaving land fallow (KC & Race, 2019; Ojha et al., 2017). The Agriculture Development Strategy 2015–2035 (ADS) in Nepal recognises the diversity of agroclimates and farmers' needs (GoN, 2014), yet appears to underestimate rural labour shortages and the impacts of increasing wildlife-farming conflict that are helping to fuel land abandonment. There are increasing structural disincentives for farmers to maintain small-scale agriculture, as input resources often outweigh revenues, and rural livelihoods are increasingly supported by alternative income streams, including remittances (Gartaula et al., 2017; Khanal & Watanabe, 2006; Ojha et al., 2022). As the landscapes of the middle hills are visibly in transition, we assess the attitudes of farmers at the forefront of change: what they

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perceive of the succeeding forest species and the associated benefits of forestation. By assessing farmers' opinions of forest succession on abandoned land, this paper addresses the implications of the following: 1) how the participatory research methodology captures farmers' perceptions, in this case, of regenerating trees on abandoned agricultural land, and 2) how farmers' perceptions of forest succession and associated species change over time since agricultural land abandonment.

We test a new approach to identifying value within transitioning ecosystems, applying mixed methodologies to gain a range of subjective and objective data. Participatory research has been a common appraisal and learning tool in the development context that empowers indigenous participants through exploratory sharing of knowledge within complex socio-ecological environments (Binns et al., 1997; Chambers, 1992). The walk and talk interview method has been applied to engage with rural farmers in their own socio-ecological context, providing time and space for farmers to be prompted by their environment in response to semi-structured interviews (Drew et al., 2022; Evans & Jones, 2011). By undertaking interviews in places that hold significance to participants, this method can prompt more meaningful answers than interviews structured in more formal settings (Evans & Jones, 2011; Pranka, 2020). The interactive research method provides additional insights, as features in the landscape such as particular tree species, prompt ideas or associations that might have been forgotten in a more formal, fixed location interview setting (Drew et al., 2022). Based on farmers' perceptions and identification of regenerating species over time and space, we endeavour to distinguish stages of succession in farmers' attitudes, recognising their needs as well as wants, to conceptualise shifting outlooks of the evolving agroforestry systems over time. Combining both quantitative and qualitative data collection interactively provides a broader insight to what is actually happening on the ground and how this is seen and experienced by the farmers. We aim to utilise these findings to build a framework for managing transitions that support farmer resilience within changing rural landscapes.

Agriculture has traditionally been the primary livelihood source across Nepal's middle hills. While it is still vital for most rural livelihoods, productive agriculture in the middle hills is struggling to remain viable, especially on smaller land parcels that are becoming more fragmented and costlier to maintain (Adhikari, 2019; Khanal & Watanabe, 2006; Pandey & Bardsley, 2019). Forest products have been an essential component of these smallhold farming systems, providing fodder for livestock, which themselves supply meat and milk products, manual power for cultivation and manure for soil improvement (Acharya, 2006; Neupane et al., 2002). Trees additionally improve landscape stability, and increase water infiltration and groundwater recharge (Badu et al., 2019; Dhungana, et al., 2020; Ghimire et al., 2014). While the presence of trees on farms—agroforestry—has been integral to traditional farming practices in Nepal, more formally recognised agroforestry techniques have increased market diversity for farmers as well as demonstrating higher biodiversity than forests in Nepal (Acharya, 2006; Shrestha et al., 2010). If managed effectively, small-scale, multi-functional farms that host native vegetation within agroecosystems can promote sustainable development for poverty alleviation and biodiversity conservation (Pandit et al., 2021; Perfecto & Vandermeer, 2010). Agrosystems developed to mimic secondary forest succession exhibit comparable soil fertility and natural pest resilience for crop cultivation, while providing a rich habitat for native species (Young, 2017), and agro-successional techniques assist with provisioning livelihoods during transitional phases of forest restoration (Pandit et al., 2021; Vieira et al., 2009). We investigate the potential of utilising agroforestry systems as a transition management approach as farmers adjust from agriculture-based livelihoods to rely more on forestation and the implications for development of policy that currently restrict such opportunities.

Resilience Theory: A Conceptual Framework for Sustainable Outcomes Through Transition Management

Socio-ecological resilience theory is used in this article to frame responses to change by anticipating and responding to the transformation of rural landscapes through stages of opportunity (Folke et al., 2021). Resilience is a response to disturbance that increases adaptive capacity, thus understanding the response of human systems to change is a key to supporting resilience (Folke, 2006; Wilson, 2012). Navigating change for sustainable and resilient outcomes in Nepal requires an understanding of the the multidimensional drivers and dynamics of interacting social and physical forces in the middle hills socio-ecological system. Out-migration from rural areas for employment and education opportunities in cities and abroad has left an older and more feminised rural population, frequently too resource-poor to cultivate all of their land (Jaquet et al., 2015; KC & Race, 2019; Maharjan et al., 2020). Much land is marginally suitable for agriculture, with small and fragmented plots situated on steep slopes, or located some distance from dwellings or roads for potential markets (Cedamon et al., 2017; Chaudhary et al., 2020; Khanal, 2018; Paudel et al., 2019). A heavy reliance on rainfall for irrigation renders much of the rural population vulnerable to changing climate patterns that affect precipitation, which can confuse crop yield and calendars, while intense rain events can cause crop damage, flooding and landslides (Bhattacharjee et al., 2017; Goodrich et al., 2017; Karki et al., 2017; Karn, 2014).

Transition management is an approach that negotiates existing dynamics and adjustments to overcome conflict between long-term ambition and short-term concerns (Rotmans et al., 2001). It also acknowledges that adjusting to change can involve a range of possible, characteristically nonlinear, development paths (Rotmans et al., 2001). Moreover, adaptive cycles of change include collapse and organisation phases in response to disturbance (Walker, 2019). Understanding the cross-disciplinary and multi-temporal, cyclic dynamics of transitions is fundamental in the context of policy making to promote resilience in communities trying to deal with change in complex systems (Adger, 2000; Holtz et al., 2008). Anticipation that highlights social learning through adjustments can help to create resilience in the face of multiple challenges, improving the adaptive capacity of a system from coping to transformation through opportunity (Rotmans et al., 2001; Wilson, 2012). Economic and environmental opportunities from forest succession in Nepal's middle hills can only be developed to their best potential, however, if they are visualised and then supported through stages of transition. By examining the temporally changing outlooks of farmers experiencing land transitions in the middle hills socio-ecological system, this research can contribute to improving resilience in transitioning rural communities by describing a management approach that acknowledges and supports staged transformations for sustainable livelihood outcomes. To achieve this goal, the perceived benefits of regenerating forest species over time are compared with agroforestry systems to develop a transition model to support farmers through landscape change.

Methods

Study Area

The study area is located in Kaski, Tanahu and Gorkha districts, in Gandaki Province, Nepal. The three districts are located in the middle hills, the most climatically diverse of five physiographic zones that extend west to east across the country. Elevation of the study area ranges from 400 m above sea level on the valley floors to 1,800 m above sea level on the ridge tops, with annual rainfall recorded between 1,500 – 4,400 mm (Open Data Nepal, 2023). While the majority of livelihoods in the middle hills have traditionally subsisted from agriculture, increasing out-migration over the last three decades has been the primary driver of socio-ecological change, resulting in aged and feminised populations unable to maintain productive agriculture (Jaquet et al., 2015; KC et al., 2017). Out-migration in the study areas is also linked to higher levels of land abandonment and increased forest cover (KC et al., 2017; Oldekop et al., 2018), while increasing remittances from international migrants has promoted a shift in the national economy. In 2020, national remittances received in Nepal contributed 24% to Gross Domestic Product (GDP), greater than the 23% GDP from agriculture, forestry and fishing combined (World Bank, 2022).

Municipalities and wards selected in each district are considered representative of the diversity as well as exposure to change in the middle hills socio-ecological system. In Pokhara Municipality, Kaski district, ward number 24 (formerly Kaskikot VDC) lies on the rural fringe of Pokhara city. Pokhara is a tourist hot spot and gateway to the Annapurna Conservation Area, which is within a day's walk of Kaskikot. Residents are exposed to urban markets and alternative sources of livelihoods in the town and through tourism opportunities. In Tanahu district, ward number 4 in Bandipur Rural Municipality surrounds the historic Newari town of Bandipur. The ward is located midway between Pokhara and the capital Kathmandu, adjacent the Prithvi Highway that connects the cities. Although agriculturally dominated, it is ethnically rich and a cultural attraction for domestic and international travellers. Ward numbers 3 and 5 are the most rural and agriculturally dependent locations, situated in Ajirkot Rural Municipality, Gorkha district. The municipality offices in Bachchek are located on a high ridge, surrounded by steep, terraced hillsides and forest. Ajirkot is located approximately 4 and a half hours by jeep from the Prithvi Highway.

Data Collection

Walk and talk interviews were undertaken to collect quantitative and qualitative data in a progressive, interactive way. The purpose of this approach was firstly to gather more detailed information as participants opened up over time, and secondly, to help participants to see their land use change from a different perspective by focussing on the details of tree knowledge and perceptions of benefits associated with regenerating species, regardless of whether or not those benefits were being utilised. In this respect, the subjective observations of participants' emotions as they contributed were as valuable as their knowledge of tree species and identification of those species regenerating on their land.

Interview participants were purposively selected from consenting respondents who had identified forest regeneration on their land, in part of a 2021 questionnaire carried out in 300 households in the nominated wards in Kaski, Tanahu and Gorkha districts. The 2021 survey respondents had been randomly selected from ward resident lists using a random number generator. Interviews were conducted with selected participants in May and June 2022 by the primary author and a Nepalese research assistant fluent in both English and Nepalese language and familiar with rural farming and forestry systems. The wards were re-visited in Pokhara

Municipality, Bandipur Rural Municipality, and Ajirkot Rural Municipality. Farmers were contacted by telephone to arrange a mutually convenient time and place to meet, including time to visit a parcel of formerly cultivated land that was succeeding with vegetation. Interviews typically commenced at the farmer's home, on the porch or courtyard outside, with an explanation of the research purpose and how the farmers' responses could contribute to the research. A short, structured interview collected broad data on the interviewee's household demographics and established the context of primary livelihood sources, land use and drivers of land abandonment, and initial opinions and use of regenerating forest species. A "mud map" was then created with the participant to illustrate the locations of actively used and abandoned land parcels relative to their home, village and distance to water sources and roads. Of 32 initial interviews, 29 respondents proceeded to visit their land to conduct a walk and talk interview. Three participants elected not to continue the research in the field: one farmer had recently sold their forested land parcel, two explained that they had migrated from that area to the town and it was too far to visit. An additional site was removed from the regenerating species data set by the researchers as the land visited had only been uncultivated for one year, however the farmer's views are included in this article. Socio-economic characteristics of the participants' households interviewed for this research are summarised in Table 1.

To visit the farmers' land, the distance from the farmers' homes, or meeting places, varied from 5 min walk through their fields to over an hour. One visit included a 15 min bus ride before an hour long walk. When each field site was reached, the researchers verified with the farmer what land the plot represented in terms of former land use and time since cultivation, and that the observed succession was a representative example of forest regeneration on their abandoned land. The farmers were asked to identify the species that they recognised and any benefits associated with that species and the evolving agroforestry system. These were all recorded by the researcher and assistant, with species recorded by their local names. Participants were also asked to estimate the age of species, whether trees were naturally regenerated, had been planted by the farmer, or were species still remnant from pre-abandonment (e.g. on terrace edges). In addition to identification of species across the abandoned land overall, an example of forest was selected by the farmer to represent typical vegetation regenerating on the land and a 10 × 10 m portion measured out by the researcher. A schematic map was created within this quadrat to illustrate the number and name of species recognised and the farmer's perception of any benefits associated with the species. During the course of conversation, participants were also asked about their perceived barriers to sustainable livelihoods from naturally regenerating forest. Attitudes throughout the course of the interviews and identification exercise were assessed through observation of the participants, noting verbal and non-verbal cues and consistency of the responses. Quotes were noted by the researchers as an expression of farmers' feelings, in addition to tone and body language. The interviews were conducted in Nepalese language and translated from Nepalese to English in the field.

Key informant (KI) interviews were also carried out in May and June 2022 with ten forest, land and conservation professionals working in government and non-governmental organisations. KIs were selected to represent a range of experts with broad experience and opinions in ministries and development sectors, including policy making in forestry and conservation. In the interviews, potential opportunities from natural regeneration on agricultural land were discussed as well as barriers or threats from emerging species on current and future management of the landscape. Interviews were all conducted

Table 1 Summary of socio-economic characteristics of interview participants (n = 32)

Characteristic		Characteristic	
Household size (median no. persons)	5	Main livelihood source (%)	
Household head (%)		*Agriculture*	84
Male	55	*Wage labourer*	3
Female	45	*Small business*	13
Highest education level (head) (%)		Median no. land parcels per household	
Limited/none	36	*Khet (irrigated low-low)*	2.0
Primary school	26	*Bari (rain-fed land)*	1.7
High school	23	*Kharbari (rain-fed upland)*	1.2
Further education	10	*Forest*	0.8
		Total	5.7
Caste (%)			
Chhetri / Brahmin	45	% households with migrants	59
Janajati	48	Median no. migrants per HH	1.2
Dalit	7		

in English language by the primary author, recorded and transcribed for thematic analysis.

Data Analysis

Quantitative results were analysed by numerically classifying categorical, numerical and discrete data and entering into SPSS (Statistical Package for the Social Sciences) for descriptive analysis. Qualitative narratives were analysed using thematic analysis (N-Vivo) to identify themes and connect data from the interview participants' feelings and field measurements such as abundance, diversity and proportion of beneficial regenerating species. Measurements of regenerating species were assessed against farmers' perceived benefits to differentiate what was present on the ground compared with what farmers saw on the ground and how they felt about it, and both measurements and attitudes were plotted against time since land abandonment.

Regenerating species identified in the quadrats were classified by botanical names and the number and diversity of species calculated against time since abandonment for each site visited. The proportion of "beneficial" species within each quadrat was estimated by the researcher to compare with regenerating species that were not considered beneficial, for the purpose of assessing the values and risks of spontaneous forest species over time and space, either as an opportunity or a threat to future ecosystem evolution and rural livelihoods. The attitudes of participants were also analysed using quotes, visual observations of participants' responses throughout the interviews, and farmers' perceptions of regenerating species to classify themes over different time periods from abandonment.

Results

Observations

The walk and talk interview methodology provided time for farmers to engage with the researchers. Some farmers were initially wary of what information was expected from them or anticipated something in return for their knowledge. However, as the research purpose was explained to the farmers, including how their participation could contribute to the research findings, the farmers visibly relaxed and opened up in their conversation. Connections with the researchers emerged over different lengths of time. Some farmers had been anticipating the visit with enthusiasm and offered refreshments on arrival. Others insisted on serving tea before visiting the land, most often if some walking was involved, while others prolonged our departure by offering refreshments on return from the fields.

Both the mapping exercise and walking with farmers to their fields demonstrated the farmers' sense of connection to the land, which in turn was stimulated by the researchers' interest (Figs. 1 and 2). There was often a sense of pride or connection to the land expressed with the sharing of knowledge, despite mixed feelings around the changing landscape. During the walk, farmers described their daily routines and pointed out features in the landscape, some of which were noted on their maps (Figs. 3a and b). Such features included tree species that they had planted on their underutilised land, the abandonment of terraces by families who had migrated to urban areas, and areas of nearby community forest. The community forest managed on the outskirts of Tindhara, Bandipur Rural Municipality, was

Fig. 1 Walking through the fields with a farmer to look at forestation on abandoned land (left of cultivated field) (Note: panoramic image distorts the appearance of contours in terraces)

Fig. 2 A farmer points out features in the landscape on the way to his abandoned land

described by one participant as "*the pride of Bandipur*". In two instances, farmers offered to take the researchers to local tourist sites of interest within walking distance of their land, and clearly enjoyed the recreational diversions. More often than not, farmers developed a curiosity during the process of measuring out the 10 m quadrats, and many offered to help. Some farmers continued with the researchers to a neighbouring site, keen to assist and to chat with the research team and the next farmer. Even the most initially reluctant of participants had engaged deeply with the researchers by the end of the data collection period.

Change in Outlook Over the Course of Conversation

Farmers' recollection of species and perceptions of benefits developed through the course of the interviews. This was anticipated in the walk and talk methodology, as farmers are prompted within their local environment to provide a rich data set associated with context (Drew et al., 2022; Evans & Jones, 2011). Observed was an increase in the number of species recognised in the field compared to the number of regenerating tree species recalled at the initial stage of the interview at the farmers' home. An average of 3 species were recalled by memory, while an average of 9 species were identified in the field (see Fig. 4). It is feasible to suppose that in addition to memory recall, the most likely tree species to be noted by farmers in the early stage interviews are those that farmers are utilising on a regular basis for livelihood purposes, such as chilaune (*Schima wallachii*), katus (*Castanopsis indica*), khanaiyo (*Ficus semicordata*), utis (*Alnus nepalensis*) and kutmero (*Litsea monopetala*). There was also sometimes confusion in the discernment of benefits from regenerating species, where "benefits" was interpreted solely as the potential income value of a tree. One participant commented "*I do not know the value of these species in the income sector*", inferring that the species that they identified should have an income value. Some farmers therefore initially responded that they affiliated "*no income benefits from regenerating species*", but as potential utilisation of succeeding species came up in conversation, or with field observations, a realisation developed of other potential non-financial values associated with the different species. In one farmer's case, where primary income depended on raising livestock, fodder collected from the regenerating forest was not seen as directly contributing to household income. However, the progress of the conversation through the extended walk and talk interview method proved valuable to determine his course of thinking. His initial statement "*we don't get any benefits from that land*" developed to "*except for some fodder*", and a little later in our conversation he added that he also collected firewood. Before we departed from his house to look at the land, he pointed out: "*we built that goat shed from chilaune regenerating on that land*". He realised through the stages of conversation that he benefitted from the forest in other ways that supported his main source of income, raising livestock. In such a moment, the walk

a b

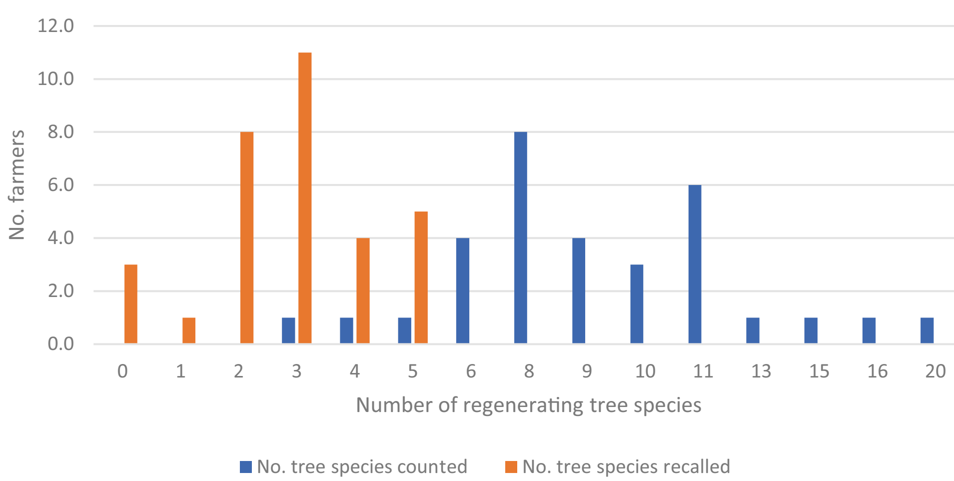
Fig. 3 **a**: Mapping land use with a participant and identifying relative distance to home, roads and water resources. **b** Example of a mud map, illustrating participant's house location, land parcels, landmarks, nearest river, roads and village.

and talk methodology helped participants to see and provide information that would otherwise remain hidden.

Change in Outlook Over Time Since Abandonment

There was a general change in perceptions of succeeding forest with time from last cultivation. Farmers who had most recently abandoned cultivation on their land (1 to 3 years ago) were clearly experiencing a sense of remorse associated with former productive land. Their perception of emerging forest was influenced by this emotional state and grievance for loss of traditional livelihoods. One farmer described the succeeding forest species as "*no use except for fodder species*" (Participant 17). Another, who had lost khet (irrigated low-land) due to a land slump 3 years prior, said: '*it was good to see the cultivation. Now the jungle is not good to see*" (Participant 15). There was a sense of defeat from failed agroforestry enterprises, wildlife conflict and the threat of free grazing and fires. When describing the regenerating forests, Participant 16 stated: "*Forest fire will destroy them, cattle will feed freely, and we will not get to see them grow*."

Fig. 4 Regenerating species recalled by farmers in interview undertaken at their home, compared to the number of species counted by farmers on a 10 × 10 m quadrat of their land



Farmers who had abandoned land 4 to 5 years ago included those who had deliberately stopped cultivating to plant cash crops such as cardamom (*Elettaria cardamomum*, common Nepali name elaichi), and farmers who had planted fruit trees in early stage succession or were planning to plant fruit trees in partially regrown forest. Most of the land left uncultivated by Participant 11 had been planted with fruit trees, supplemented with manure from her buffaloes. Participant 25 described the challenges of keeping invasive ground species clear of cash crop plantations for optimal growth: "*Cardamom didn't grow well and forest has regenerated around the cardamom crops*".

In general, the alternative land uses chosen by farmers were perceived to require less labour than crop cultivation. More often than not, there was some degree of income generation affiliated with any activity initiated on the formerly cultivated land. Shifting from a reluctant acknowledgement that regenerating tree species provided only fodder, farmers began to recognise the contribution to livelihoods of fodder species. Some were also assisting regeneration through collection and planting of selected species. While agriculture remained their preferred livelihood source, in general the supplementary benefits of trees for fodder and firewood were increasingly recognised. Participant 10 had planted champ (*Michelia champaca*) trees, having sourced the seedlings from her local forestry office, "*because there was no benefit in abandoned land*".

Based on conversations and attitudes around changing landuse, farmers appeared to be in a period of adjustment after 6 years of land abandonment. From 6 to 10 years, farmers realised benefits of both agriculture and forest. Maintenance of crop cultivation in the short term was important for rural food security, while forest was recognised as a longer-term investment. Some farmers were intentionally leaving land to succeed through grass, shrub and forest stages for livelihood gains such as fodder and firewood.

> "*We plan to cultivate [crops] on some of the forested area next year, but will leave some forest for cutting fodder, firewood and timber*" (Participant 30).

After ten years of land abandonment, farmers had generally moved to tolerate, accept, or welcome forest succession. Those who had migrated from rural farmland to towns, or had migrated to alternative primary incomes or livelihoods, were indifferent in attitude, appearing to have "moved on" in mind as well as body. Farmers who still relied primarily on agriculture for their livelihoods preferred to cultivate closer to home, collecting fodder and firewood from the more distant abandoned land.

> "*The land is very steep so we prefer to cultivate land closer to home and collect fodder & firewood from the trees*" (Participant 13).

After 12–15 years of abandonment, fodder sourcing from the forest became less important and the succeeding trees were referred to as private forest. As the landscape shifted from agriculture to forest, there was also a transition in the language used by some farmers to describe it, often interchangeably between private forest and the former land type (e.g. kharbari, rain-fed uplands). Participant 7 stated "*we tried to manage the forest and fodder trees, but when we moved it was too far… [and] time consuming and expensive to come*".

Forests aged 20 to 40 years generally formed a portion of multi-functional agroforestry farming systems, with regenerated species valued for income (timber sales) and subsistence livelihoods (fodder, firewood, timber). Additionally, indirect benefits were recognised, such as improved land stability and improved hydrological functions. Out of farmers visited in 2022 who associated regulating services with regenerating trees on their land, there was a correlation between the number of services and the age of the forest. Of the species identified by farmers, chilaune and utis were most commonly associated with improved land stability, and bamboo (*Bambusa vulgaris*) most commonly cited to improve soil and groundwater recharge and reduce rainfall runoff. Additionally, trees were recognised for their "environmental importance", associated with "clean air" and "oxygen", and were described as aesthetically pleasing. "*More greenery is more attractive*", commented Participant 26.

Measured Benefits

The proportion of beneficial species measured on 10 m quadrats of land in transition from agriculture to forest varied from 50 – 100%. However, the majority (80%) of farmers recognised more than 90% of regenerating species on their land as having some benefits. In the 2021 survey with 300 hill farmers, the total number of regenerating tree species on private land identified from farmers' memory (including shrubs and fruit trees) was 41 species. In comparison, over the three districts visited in the field in 2022, 77 species of trees (listed in Appendix A) were identified in naturally regenerating forests using the walk-and-talk method, ranging in elevation from 400 – 1800 m above sea level. Perceived provisioning services associated with the regenerating tree species identified by farmers in the quadrats are shown on Fig. 5, with subsistence livelihood benefits (fodder and fuelwood) most cited. Timber was valued for income potential as well as building structures on farmers' own land.

While the focus of the research was to assess potential benefits of regenerating tree species on former agricultural land, the stages of forest succession also presented a range of shrubs and other small herbaceous species that were identified by the farmers. These varied from large angeri shrubs (*Melastoma normale*) and ainselu vines (*Rubus ellipticus*)

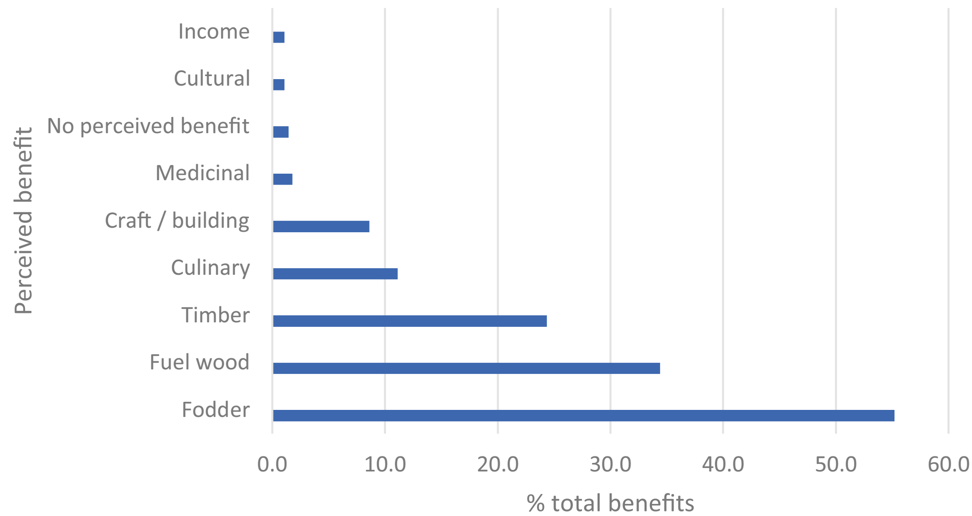


Fig. 5 Perceived provisioning services of regenerating tree species (listed in Appendix A)

known for wild fruit, to ground dwelling plants and root crops. The majority of ground cover species were stated to have some beneficial use. Two ground cover species identified by farmers on their regenerating land, *Leucaena leucocephala* and *R. ellipticus,* are listed in the Global Invasive Species Database as alien invasive species in Nepal (Global Invasive Species Database, 2023), despite having benefits perceived by farmers, such as fodder, wild fruit and fuelwood. Furthermore, *L. leucocephala* has been promoted in Nepal by the Nepal Agroforestry Foundation as a multi-purpose fodder tree, providing shade for plantation crops, shelter from wind and improves land stability and soil moisture (Acharya & Kafle, 2009; Pandit et al., 2014). Some species, most notably the invasive species *Ageratina adenophora* (synonym *Eupatorium odoratum*, locally called banmara or banmasa) were perceived differently by farmers, with decreasing favour over time since last cultivation. For example, in early-stage regeneration, *A. adenophora* was used as fodder, as was *Artemisia vulgaris* (locally known as tite pati). However, in later stage regeneration when fodder tree species had established, trees were preferred for livestock feed and invasive species perceived less favourably. Additionally, some grass species were perceived as weeds and of no perceived benefit at all.

Table 2 presents examples of ground species that were identified by farmers when questioned about the species that had regenerated within the 10 m quadrat of their land. Based on farmer knowledge, the list provides a broader picture of the changing landscape and perceptions of what land owners see within that change and potential opportunities that might be emerging during landscape transitions from exploiting biodiversity.

In summary, Fig. 6 illustrates measured forest succession on abandoned agricultural land in Nepal's middle hills, perceived benefits affiliated with forest species over time, and evolving perceptions from loss to gain with increased time from abandonment. As vegetation encroaches land following abandonment of cultivation, there is a change in farmers' perceptions over time. With increasing size, abundance and diversity of forest species since land abandonment, species values shift from subsistence livelihood provisions such as fodder and fuelwood to income generating resources, including timber and non-timber forest products. The changing outlooks of farmers indicates an adjustment period balancing short-term food production and security needs through to recognising longer term rewards from forest resources. Application of these findings to manage transitional phases for long-term sustainable livelihood and biodiversity conservation outcomes is discussed below.

Discussion

Spending time with rural farmers to understand their socio-ecological context illustrated the complexity, scale and flow-on effects caused by, and resulting from, decisions made at the household level. The walk and talk methodology allowed farmers to open up over time, while also help them to see information that can be missed in more formal or structured interview settings. The methodology therefore provided greater levels of detail over time and space. The collection of both subjective and objective data embedded the observations of feelings with biophysical ecosystem responses to change, enriching the data for practical application in transition management. Although the methodology can be more time consuming, the flexibility to explore branches of information and pursue detail provided valuable information that was much richer than the first phase questionnaires, and in fact took less time than the 300 surveys carried out in 2021. Whether land cover change is a result of a conscious decision (e.g. to grow cash crops under the shade of succeeding forest species) or a consequence of other causes (e.g. out-migration leading to labour shortage), farmers' perceptions

Table 2 Farmers' perceived benefits of identified small plants and shrubs regenerating on abandoned agricultural land

Botanical name	*Common/local name*	*Benefit identified by farmer*
Agave spp.	Ketuke	Fencing
Ageratina Adenophora	Banmara, Banmarsa	Fodder, composting
Ageratum haustonianum	Ghandey jhar, Nilo ghandey	Composting
Albizia lebbeck	Sirris	Fodder, banana ripening
Artemisia vulgaris	Tite pati	Fodder, compost, insecticide, medicinal
Arudinaria falcate	Nigalo	Doko (basket) making
Asparagus racemosus[a,b]	Kurilo	Food, medicinal
Atylosia scarabaeoides (L.) Benth	Jangali jhari	Fodder
Barleria prionitis	Bajara danti	Medicinal
Berberis aristate[a,b]	Chutro	Fruit
Colebrookea oppositifolia Sm	Dhursili	Fodder, medicinal
Costus speciosus[b]	Bet lauri	Medicinal root
Crataeva religiosa	Sipligan	Culinary
Cryptolepsis buchanani[b]	Bhui champa	Medicinal
Curcuma longa[b]	Besar	Culinary, medicinal
Dioscorea alata	Gita, tarul (yam)	Root vegetable
Eurya cerasifolia	Pate	Broom
Ficus glaberrima	Amaro	Fruit
Imperiata cylindrical	Siru	Thatch, forage
Inula cappa[b]	Gaitihare	Medicinal
Justicia adhatoda[b]	Asuro	Medicinal
Leea macrophylla	Galeni	Fodder, medicinal
Melastoma normale	Angeri	Fruit, fodder
Mimosa rubicaulis	Areri	Medicinal
Mussaenda macrophylla Wall	Dhobini	Medicinal
Rubus ellipticus	Ainselu	Berries, fodder
Saurauria nepaaulensis	Gogan	Fruit
Scutellaria discolor Colebr	Rato pati	Fodder
Tinospora sinensis[a,b]	Gurjo	Medicinal
Toddalia asiatica	Mainkara	Medicinal
Tribulus terristris L.[a,b]	Gokhur	Medicinal
unidentified	Niro	Edible fern
unidentified	Niuro	Treat mites in chicken coop

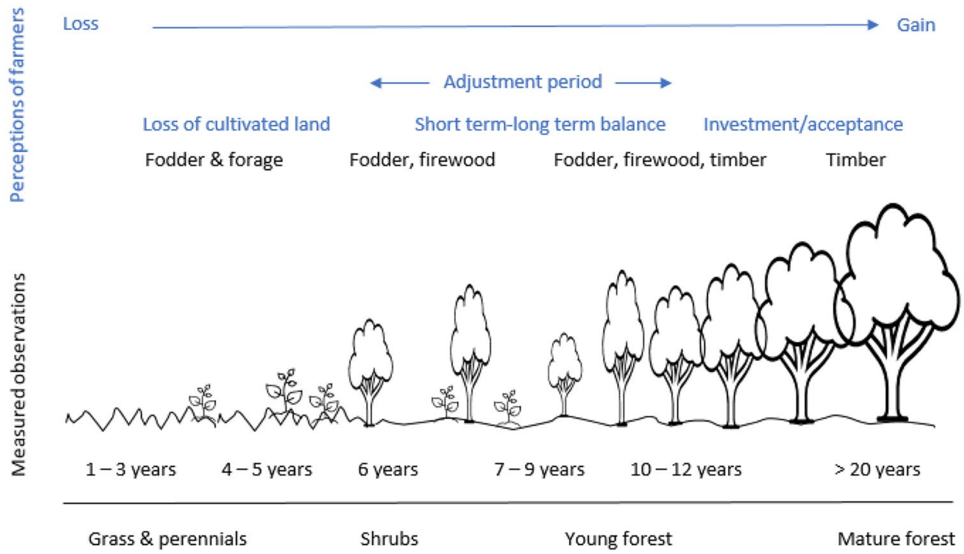
[a]Medicinal plants prioritised by the Government of Nepal for medicinal research (Amatya et al., 2018)

[b]Listed in National Register of Medicinal Plants (IUCN, 2000)

of tree species appeared to be influenced by their livelihood needs and identity – their sense of who they are and belonging associated with place (O'Neill et al., 2008). Furthermore, the loss of livelihoods through landuse change therefore removes a part of their identity that was integral to their lives (O'Neill et al., 2008). Walk and talk interviews with farmers in rural wards in three hill districts also demonstrated how perceptions of the changing landscape and species composition can shift over time. While studies have showed negative perceptions and feelings of "shame", "sadness" and loss of traditional heritage with abandonment of agricultural land (Benjamin et al., 2007; Drenthen, 2018; van der Zanden et al., 2018), Friedrich and Wüstenhagen (2017) proposed that evolution of emotions over time can influence perceptions when evaluating threats or opportunities. Perhaps it is only by spending time, intimately developing mutual understanding of the transition processes, that researcher and farmer can develop such knowledge.

The majority of species observed regenerating on abandoned agricultural land at the case study sites had cited benefits by farmers. These ranged from currently utilised contributions to livelihoods such as fodder and fuelwood, to income generation from timber. The researchers' interest in the regenerating species also prompted farmers to view succeeding vegetation from different perspectives, generating a broader response of potential benefits as participants recognised additional uses of species for craft and cultural purposes, medicinal properties and food sources that had

Fig. 6 Stages of forest succession from natural and social observations in middle hills, Nepal



been overlooked. Uses were cited even for invasive species that could have productive outcomes (e.g. composting). Of regenerating tree and groundcover species, 21% and 29%, respectively, are listed in Nepal's National Medical Register (IUCN, 2000). Not all participants perceived the same benefits of species, and benefits of some species changed with time since land abandonment (e.g. *A. adenophora*).

Socio-ecological resilience theory integrates the connectedness of social and ecological systems and an understanding of the patterns and processes of time, space and meaning (Gunderson & Holling, 2002; Westley et al., 2002). The theory assumes that inter-connected socio-ecological systems are progressing through adaptive cycles of renewal and adjustment, and that disturbance is part of the process of re-organisation and renewal (Gunderson & Holling, 2002; Plieninger & Bieling, 2012). In renewal phases, loss can lead to the release of capital (e.g. regenerating species), and learning leads to growth and understanding of capacity (Gunderson et al., 2002; Walker, 2019). In a resilient socio-ecological system, disturbance can create the potential for new opportunities through innovation and development (Folke, 2006). In assessing the potential benefits of regenerating species on abandoned agricultural land, the perception of opportunities from the evolving landscape is a measure of resilience. The capacities of complex socio-ecological systems, however, must be understood to enable development within the social and ecological spheres that are co-evolving (Folke et al., 2021). In this example of forest succession, resilience from disturbance – as a consequence of the changing social dynamics – requires social re-organisation to adjust to the changing ecological landscape. In the field studies, the benefits of regenerating forest resources changed over time, and shifting perceptions from the loss of one landscape, and affiliated livelihoods, to acceptance or even a sense of "investment" associated with regenerating tree species, illustrated farmers' abilities to adjust to change over time. Farmers demonstrated a growth in resilience through phases of recognising benefits and adjusting their perceptions from negative to positive with the succession of forest (Fig. 6). As forest species succeed on former agricultural land, different values of agroforestry could be identified to meet farmers' needs while in transition to increased forestation.

Socio-ecological resilience is a forward-looking approach that requires adjustment through learning as part of adaptation (Folke, 2021). In the same sense, transition management acknowledges cycles, or stages of adjustment, to shift from a starting point to end goal (Rotmans, 2001). A conceptual vision ("ABC") for managing the transition from agriculture to forest in the landscape to build resilient rural communities is illustrated in Fig. 7, based on farmers' perceptions of different values of forest products at different successional stages. As grief is a natural response to loss, establishing a long-term vision in early-stage succession could help farmers to navigate landscape transitions and the sorrow arising from the physical loss of crops, the agricultural landscape or psychosocial identity of being a farmer (Friedrich & Wüstenhagen, 2017; Goldsworthy, 2005; Lee, 1994). To achieve this, there first needs to be an acknowledgment of feelings of loss or grief, which might be expressed as "sadness, anger, helplessness, guilt or despair" (Raphael, 1984, p33), including initial resistance to change. If periods of adjustment are each recognised as transitions towards a long-term goal, these could be managed step-wise as stages to achieving the end vision. By recognising change in outlooks at the onset of this process, opportunities could be identified within each transition stage to focus farmers' outlooks from the loss of their production-oriented identity to ownership of other multi-functional farming components,

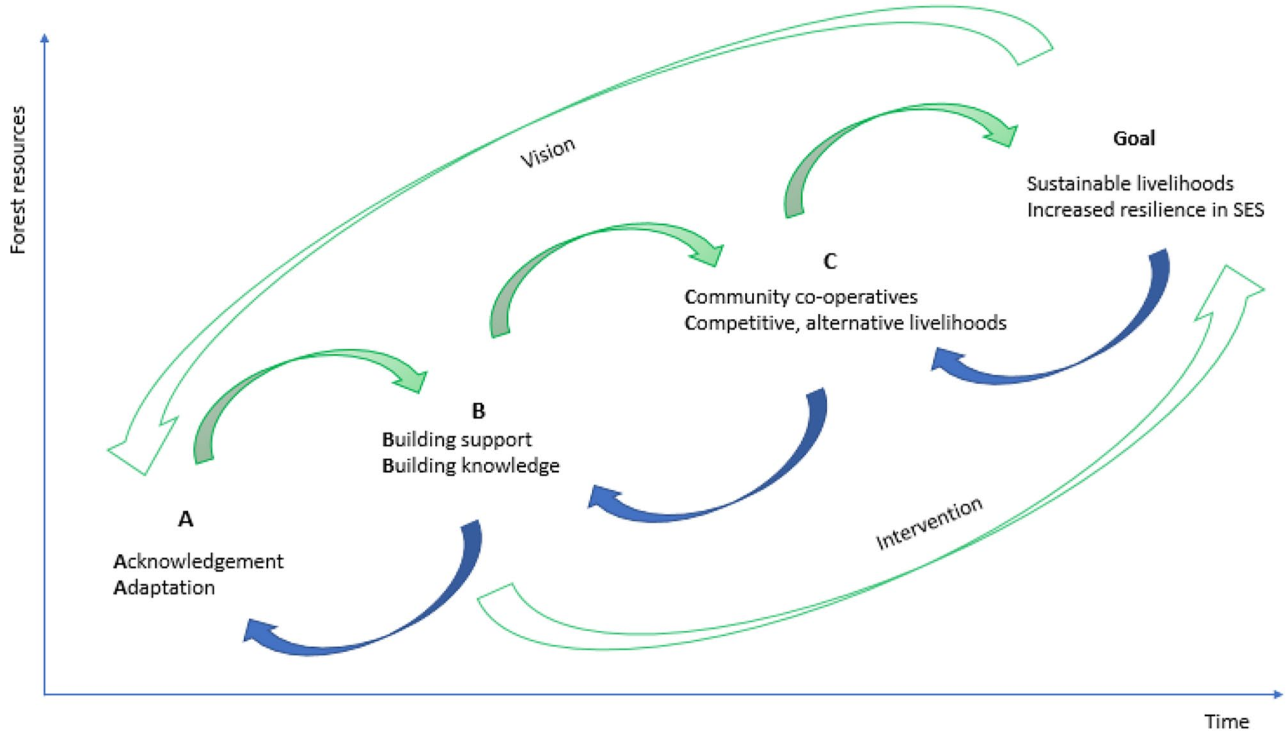


Fig. 7 Evolution of transitioning landscapes and farmer experiences – **A**: acknowledgement of loss and adaptive strategies established by end goal (vision); **B**: Building support and knowledge, led by local government and institutions; **C**: Creation of community-run co-operatives and alternative livelihoods that offer diversity in a competitive market. Re-organisation phases (blue) are pre-empted by management intervention, while growth phases (green) are supported by informal and formal mechanisms

including participatory biodiversity conservation (Burton & Wilson, 2006; Khadka & Nepal, 2009). Such responses could assist with adaptive capacity through foresight to navigate degrees of focus and build resilience (Folke, 2006; Rotmans et al., 2001). In adaptive cycles, periods of growth and development are characterised by exploring new opportunities and resources, which in this scenario could be connected and regulated through formal and informal support mechanisms (Walker & Salt, 2012). Uncertainty and experimentation can also be anticipated and managed through intervention during re-organisation phases.

Barriers to forest succession identified by participants in the field included physical as well as motivational issues. The primary resources and incentives needed to maintain or enhance succeeding forests in the longer term were identified by the 2021 survey respondents first and foremost as economic (e.g. assets, income, subsidy), followed by human (e.g. labour, skills, knowledge) inputs. Participant 1 spoke of these challenges to developing forestry growth on the land: "*We are poor, we have no money to invest on the land… and we don't make enough from the land, so some family has had to migrate to earn an income. That is a reason for our demotivation*." Transporting products to markets was also perceived as a significant barrier to achieving sustainable livelihoods from forest species regenerating on former agricultural land: "*Improved transport would enable timber and forest products to be sold at the market*" (Participant 27).

Agricultural development in Nepal has greater potential to utilise the opportunities of niche markets that suit the many agroclimates and systems (GoN, 2014). To exploit such markets, small-scale farmers could be further supported through community-level co-operatives, promoting inclusive service delivery of locally produced resources (Gauli & Hauser, 2009; Jaishi et al., 2015). The existing agricultural export trade already dominated by local products, such as tea, cardamom, fruit, ginger, medicinal and aromatic plant products, indicates the potential for niche products from marginal, middle-hills farming systems that can be integrated with trees in biodiverse, multi-functional farming systems. Field studies showed a growing interest in high value market products, with 7 of the 14 farmers interviewed in Ajirkot Rural Municipality having planted cardamom, while 7 of the 32 farmers interviewed had planted fruit trees on uncultivated land succeeding with shrubs and small trees. Two farmers interviewed had planted ginger. The deliberate act of planting implies that the farmers have been motivated by the reward of receiving some benefit. Integration of agroforestry practices for food and income benefits within patches of naturally regenerating trees could be scaled up to exploit niche market opportunities.

Policy Implications

In Nepal, policies across different sectors have often failed to recognise the complex dynamics related to agriculture, migration and forestry (GoN, 2014; Ojha et al., 2017). Agroforestry is not currently governed by its own policy or institutions but falls within agricultural and forestry policies that are segregated, and thus the potential to exploit tree resources from multi-functional agricultural landscapes on private land is limited by forest regulations and bureaucracy, as well as a lack of local knowledge and adaptive capacity by farmers (Cedamon et al., 2017; Pain & Marquardt, 2021; Sapkota et al., 2020). The ADS recommends development and integration of agroforestry models into existing forest practices by identifying forest products that have both social and economic benefits, as well as improved integration of multi-ministry policies and plans (GoN, 2014).

The recognition and management of forest succession in the middle hills could become more integral of regional development via a staged agroforestry approach to transition livelihoods in association with the changing landscape. Targeted support during successional forest transition could be provided at a local level to assist with establishing a vision that accommodates different agroclimates and products. Support needs to include technical training in species benefits and agroforestry practices to exploit the advantages of diverse ecosystems for livelihoods, resource efficiency and biodiversity conservation as well as mainstreaming market linkages that promote private forest-based enterprises (dos Santos et al., 2021; Perfecto & Vandermeer, 2010; Vieira et al., 2009; Young, 2017).

> "*They will get benefits, people will be convinced of that. Other thing is, through the institutions, government and community institutions, some sort of organised activities, interactions, trainings, how they are getting benefitted, how they could get benefited. This should be definitely organised for them locally*" (KI 2).

Local regulatory support to encourage respect of property boundaries would also assist faster pioneer establishment by preventing livestock interference on early stage succession during transition. Also, responses to threats to species conservation or beneficial regeneration, such as invasive alien species extending beyond private land to public land and protected areas, often needs to be implemented in early stage transition, when perceived potential benefits of these species are higher. Exploiting potential benefits to manage these species, via composting weeds for example, could turn threats into opportunities within multi-functional agricultural landscapes. Using the invasive species *A. adenophora* as a feedstock for making biochar has proven successful in a middle hills livelihoods project for improving soil fertility and crop productivity as well as enhanced carbon sequestration potential (Pandit et al., 2021).

More broadly, to improve livelihoods formerly reliant on crop cultivation, regenerating trees could be incorporated into the valuing of complementary, low-labour farming systems, during transition to forest. Some one third of regenerating trees identified by farmers in this study are recognised as commonly forming part of productive agroforestry systems in the mid-hills (Amatya et al., 2018; FRTC, 2019), a farming practice that was repeatedly commended by the KIs:

> "*We know that the solution is different types of agroforestry systems that fit in that landscape*." (KI 3).
> "*Depending on the local context, in some places other cash crops can be introduced, tree crops, tea, coffee. These types of things which are generally not destroyed by wildlife…there are options to scope, to take this as an opportunity to really plan and promote [a] new type of farming system in the middle hills*" (KI 4).

Farmers who are formally engaged in agroforestry are able to benefit from greater diversity in terms of livelihood resilience as well as improving biodiversity overall. In the Terai region, labour and water shortages and lack of technical knowledge are prompting farmers to plant trees instead of mono-crop cultivation as the trees are much lower maintenance (FRTC, 2019). Seizing opportunities from potential non-timber forest products, or larger schemes such as credits for carbon sequestration or biodiversity conservation, could improve resilience through various alternative livelihoods that are not as labour intensive. Support to take advantage of, and nurture, succeeding forest patches could be actioned through the Government of Nepal's partnership with the World Bank's Forest Carbon Partnership Facility to deliver both local and global beneficial outcomes (Di Sacco et al., 2021; World Bank, 2021).

Transformation of agricultural landscapes to benefit farmers' livelihoods from succeeding forests is a long-term goal. Transition management could be applied to achieve this goal by identifying opportunities and progressing stepwise through intervention and re-organisation. Through participatory rural research, farmers are recognised as playing a central role in providing a range of innovative solutions to meet the needs of local social and ecological conditions (Binns et al., 1997; Khatri et al., 2017; Leach et al., 2012). Adjustment is a continuous process and requires management that can respond to the multiple stages through transition that anticipates actors' concerns through different stages. Through public forums, programs that allow people to reflect on what they have lost or gained is an important step in transition, as well as policy development. The division of policy across sectors in Nepal has created limitations and constraints to manage transition at a landscape level (Khatri et al., 2017). The diversity and resources from secondary forests has largely been overlooked due to forest bureaucracy and other top-down power structures (Pain & Marquardt, 2021). Policy makers and institutions at all levels need to acknowledge the changing socio-ecological system in the middle hills, and coordinate between stakeholders and agencies to manage the landscape complementary to characteristics of ecological zones (Khanal et al., 2020). ‘Bottom up’ strategies enable local people to express their challenges and needs through decentralisation and diversity (Binns et al., 1997; Chambers, 1992), and are best supported by local government and institutions supporting community-run initiatives over time. Recognising the importance of diversity, instead of econometric production, can build resilience that is determined both by the capacity for long-term adjustment and flexibility in governance to meet household needs through the transition (Biggs et al., 2012; Binns et al., 1997; Chapin III et al., 2009; Leach et al., 2012).

Conclusion

The encroachment of forest on abandoned agricultural land in the middle hills of Nepal is both a response and a driver of the changing socio-ecological system. Due to the complexity and inter-connection of drivers that cause land abandonment, the effects cannot be resolved in isolation, nor with any single solution. Participatory field research is effective for assessing sustainable solutions within such contexts by engaging with farmers to identify real-time needs while exploring long-term goals (Chambers, 1993; dos Santos et al., 2021). The walk and talk methodology applied here has illustrated not only the value of spending extended time with farmers, resulting in more detailed information, but also demonstrated how species benefits can range across time and space. Furthermore, negative emotions associated with loss of productive agricultural land and, potentially, farmers’ identity, can evolve over time to develop an increasing acceptance of agroforestry.

Understanding changing attitudes during landscape transitions could help people to anticipate and adapt through identifying opportunities at stages of transition, rather than focussing on grief from lost identity and livelihoods affiliated with former productive agriculture. With out-migration over the last three decades, alternative income streams in Nepal have decreased the dependence on agriculture and increased the purchasing power for food security in the middle hills of Nepal (Gartaula et al., 2017; KC & Race, 2020; Pandey & Bardsley, 2019). Alternative livelihoods – and the decisions driving them – have created resilience in some rural communities through flow-on effects. Yet, those alternative land uses that meet farmers’ primary livelihood and income generation needs must also respond to intersecting changes across the socio-ecological system to assist households to navigate the phases of transition. In areas challenged by agricultural dependence, institutional support that provides incentives or helps to coordinate community co-operatives, could provide stepping stones to sustainable development. To achieve this for sustainable outcomes in rural communities, alternative development pathways must be diverse and adaptable for improved resilience. Humans response to change must be navigated, as well as environmental, economic and socio-political impediments. Through anticipation and visualising positive outcomes at the local level, individuals and communities could manage step-wise transitions to a shift in outlook from loss to gain from land-based livelihoods. Our findings provide an example and a transition management framework that could be developed at a broader scale to address multiple contemporary challenges that are destabilising local socio-ecosystems. Applications include local adaptation to climate change and restoration of ecosystems for biodiversity loss, which require responses that are relevant and reflexive at local scales, while contributing to mitigating global crises.

Appendix A

Table of regenerating tree and shrub species identified by farmers.

Botanical name	*Common/ Local name*	*Direct benefit identified by farmer*	*Agroforestry systems in Nepal* (FRTC, 2019)	*Traditional uses listed in Medicinal Plants* (IUCN, 2000)
Acacia catechu	Khair	Timber, (income)		Gastrointestinal, ulceration, skin
Aegle marmelos	Bel	Religious		Laxative, digestive, fevers
Albizia lebbeck	Siris	Fodder, timber, fuelwood	Small-scale woodlots	
Alnus nepalensis	Utis	Fuelwood, timber, building, craft, income	Agrisilviculture, Agrosilvipasture, woodlots	
Antidesma acidum	Archale	Fodder		
Artocarpus lakoocha	Badahar	Fodder, fuelwood, timber	Silvopasture, home garden	
Arundinaria falcata	Nigalo	Craft (*doko*), fodder		

Botanical name	*Common/ Local name*	*Direct benefit identified by farmer*	*Agroforestry systems in Nepal* (FRTC, 2019)	*Traditional uses listed in Medicinal Plants* (IUCN, 2000)
Bauhinia purpurea	Tanki / Bajuri	Fodder, fuelwood, timber, building, craft, medicinal		Gastrointestinal, anti-dysenteric
Barleria prionitis	Bajara dante	Fodder		
Berberis aristata	Chutro	Medicinal		Multiple uses from root & bark
Bombax ceiba	Simal	Craft, building, fodder		Gastrointestinal (flower), stimulant (root & bark), inflammation (gum)
Brassaiopsis hainla	Chuletro	Fodder, fuelwood		
Buddleja asiatica	Bhimsen Pate	Fodder		
Busera simaruba	Mallato	Timber		
Callicarpa arborea	Ghunaulo	Fodder, fuelwood		
Carissa carandas L	Paner	Fodder, edible fruit		
Castanopsis indica	Dhale katus	Fuelwood, timber, building, fodder	Agrisilviculture, home garden	
Cedrela toona	Tooni	Fuelwood, timber		
Choerospondias axillaris	Lapsi	Food, fodder, fuelwood	Agrisilviculture, Hortisilvipasture, Agrisilvihorticulture, Hortiagriculture, home garden	
Cinnamomum tamala	Tej pat / Gwassey	Spice	Agrisilviculture, Agrisilvihorticulture, Hortisilvipasture	Rheumatism, colic, diarrhea
Citrus medica	Bimiro	Fodder, cultural		
Colebrookea oppositifolia Sm	Dhurseli	Fodder		
Crataeva religiosa	Sipligan	Food (*achar*)		Gastrointestinal, urinary infections
Dalbergia sisso	Sissoo	Timber	Timber trees in upper storey	
Daphniphyllum himalense	Rakchan	Timber		
Diospyrus malbarica	Tindu	Fuelwood, crafting timber, edible fruit		
Emblica officinalis / Phyllanthus emblica	Amala	Fruit, fuelwood		Laxative & diuretic, Ayurvedic constituents, respiratory illness
Erythrina subrosa	Phaleto	Income, wood craft / building		
Eurya acuminata	Jyanu	Fodder		
Eurya cerasifolia	Pate	Timber		
Falconia insignis	Khirro	Crafting musical instrument		
Ficus auriculata	Dumre	Fodder		
Ficus glaberrima	Pakhuri	Fodder, fuelwood	Home garden	
Ficus hispida	Khasre / Thotne	Fodder, fuelwood		
Ficus lacor	Kapro	Fodder, fuelwood	Silvopasture	
Ficus nerifolia	Dudhilo	Fodder, timber		
Ficus oligodon	Nimaro	Fodder, fuelwood		
Ficus religiosa	Pipal	Fodder, medicinal		
Ficus semicordata (synonym Ficus cunia)	Khaniya	Fodder, fuelwood	Silvopasture, Agrosilvipasture, home garden	
Ficus semicordata var montana	Rai Khaniya	Fodder		
Ficus subincisa	Bedulo / Gedulo	Fodder		
Fraxinus floribunda	Lakuri	Fuelwood, food, building timber		
Garunga pinata	Dabdabe	Fodder, timber		
Gaultheria fragrantissima Wall	Patpate, Dhasingare	Fodder, fuelwood		Insecticide, muscle liniment, mouthwash

Botanical name	*Common/ Local name*	*Direct benefit identified by farmer*	*Agroforestry systems in Nepal* (FRTC, 2019)	*Traditional uses listed in Medicinal Plants* (IUCN, 2000)
Grewia optiva	Phusre	Fuelwood	Agrisilvihorticulture	
Hydrangea anamola	Bhahuni khat	Fodder		
Lagerstroemia parviflora	Bodhairo	Fuelwood, fodder		
Leucaena leucocephala	Ipil ipil	Fodder, fuelwood	Silvopasture	
Lindera neesiana	Sil Timur	Fodder, medicinal, fuelwood		
Litsea monopetala	Kutmero	Fodder, fuelwood, medicinal	Agrosilvipasture, Silvopasture	
Machilus odoratissima	Kaulo	Fodder		
Madhuca longifolia	Mahuwa	Fuelwood, fodder, building, paper making		
Maesa indica	Bilaune	Fodder		
Mallotus philippensis	Sindure	Fodder, fuelwood		Anthelmintic, wounds, purgative
Melastoma normale	Angeri	Food, fuelwood, fodder		
Melia azedarach	Bakaino	Fodder, fuelwood, building, food (*achar*)	Agrisilviculture, Silvopasture	
Mimosa rubicaulis	Areli / Boksi ghans	Fodder, fuelwood		
Myrica eculenta	Kaphal	Fodder, timber, edible fruit	Agrisilvihorticulture, Hortisilvipasture	Antiseptic, respiratory
Pinus roxburghii	Sallo	Fuelwood		
Premna interrupta	Ginneri, Gideri	Fodder		
Prunus cerasoides	Paiyu	Fodder, timber	Agrisilviculture	
Psidium guajava	Guava	Fruit	Hortiagriculture	
Rhododendron arboreum	Gurans	Fuelwood	Agrisilviculture	
Rhus chinensis	Bhakimlo	(observed as seedling)		
Rubus ellipticus	Ainselu	Fodder, fruit		
Schima wallichii	Chilaaune	Fuelwood, timber, building, fodder, branches used as support for climbing vegetables	Agrisilviculture, Agrosilvipasture, Silvopasture, small-scale woodlots, home garden	
Semicarpus parviflora	Bodhairo	Fodder, fuelwood		
Shorea robusta	Sal	Timber, fuelwood, fodder	Small-scale woodlots	
Syzygium cumini	Kyyamuna	Fuelwood		Gastrointestinal, respiratory, ulcers
Syzygium jambolanum	Jamun	Fodder		
Terminalia bellerica	Barro	Fuelwood, fodder		Multiple uses, including Ayurvedic preparation
Terminalia elliptica	Saaj	Fuelwood, timber		
Thysanolaena maxima	Amliso / amriso	Fodder, craft (broom making)	Agrosilvipasture, Hortiagriculture	
Trachyspermum ammi	Jwano	Fodder		
Tribulus terristris L	Gokhur	Fodder, medicinal		Urinary affections
Woodfordia fruticosa	Dhaire	Fodder, fuelwood		Gastrointestinal, gynaecological
Zanthoxylum armatum	Timur	Spice, medicinal, fuelwood, fodder	Hortisilvipastoral	Insecticide, gastrointestinal, skin, fever
Total no. species:	77		22	16

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Authors Contributions Nicola McGunnigle: Conceptualisation; Methodology; Data curation; Funding acquisition; Formal analysis; Project administration; Visualisation; Writing – original draft & revision; Writing – review & editing. Douglas K. Bardsley: Conceptualisation; Methodology; Supervision; Visualisation; Writing – review & editing. Ian K. Nuberg: Conceptualisation; Funding acquisition; Supervision; Visualisation; Writing – review & editing. Edwin Cedamon: Conceptualisation; Methodology; Supervision; Writing – review & editing. Bishnu Hari Pandit: Methodology; Data curation; Writing – review & editing.

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Availability of Data and Materials Not applicable.

Declarations

Ethical Approval The data used in this paper is part of a Ph.D. project of the lead author, researching regenerating forests on underutilised and abandoned land for sustainable development in middle hills Nepal. Ethical clearance was obtained from the University of Adelaide, number H-2021–099, and as such was assessed as compliant with the National Statement on Ethical Conduct in Human Research 2007 (updated 2018) and the Australian Code for the Responsible Conduct of Research.

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