Examining Ecosystem Service Change in the Miyun Watershed, China Through Stakeholder-driven Visions of the Future

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Abstract

Humans derive many benefits from natural environmental systems. These benefits are commonly referred to as ecosystem services, and include freshwater, food, fuel, fiber, soil formation, opportunities for recreation, and climate regulation among many others. Many ecosystem services are in decline, and future changes in ecosystem services are uncertain due to the complex interactions between anthropogenic factors (e.g. population increases and technological change) and non-anthropogenic (e.g. climate, physical geographic conditions, etc.) factors. In developing countries, rural populations are often heavily reliant on provisioning ecosystem services natural resources provided by their local landscapes for their livelihoods. Thus, changes in the quality or availability of ecosystems services will have the most immediate, and likely most severe and enduring, impacts on rural populations. Yet because of the complexity of social-ecological systems, it is difficult to predict how landscape changes may affect ecosystem services and, in turn, affect those who fundamentally depend on these services for their well-being. Scenario planning is a participatory method that can be used to examine a range of plausible future development trajectories. It can be used to prepare for rapid, unexpected and poorly understood changes in ecosystem services. This thesis uses scenario planning to examine plausible future ecosystem service dependency changes in the Miyun watershed in the northern region of China. To do this, I first conducted regional scenario planning exercises in three study villages. I then compiled regional scenarios of "plausible future development," and assessed sub-regional responses to these scenarios. The literature on scenario planning methods and findings focuses on the creation of scenarios and what is called a "final future narrative." This thesis aims to go further by soliciting sub-regional response to scenarios and learning specific processes villages may engage in in order to reach scenario futures. Chapter 1 gives an introduction to the thesis and sets the stage. Chapter 2 reviews literature relevant to the management and ecosystems services and scenario planning. Chapter 3 details the sub-regional responses to common regional scenarios. Chapter 4 uses the divergent scenario outcomes to explore plausible future changes in ecosystem service dependency of the three study villages. It explores changes in ecosystem service dependency of rural populations as implied by the scenarios, and aims to understand livelihood vulnerability as a result of plausible changes in ecosystem services. Next, scenarios were compared to baseline ecosystem service dependency measures for village livelihood activities, and plausible future ecosystem service dependency measures were determined for each major category of livelihood. Chapter 5 concludes. Overall, the findings show study villages are diverse in the processes used to reach regional scenario futures. This project reflects the adaptive co-management literature and highlights the importance of understanding diversity in local responses in order to meet regional policy goals. Results indicate that dependency on ecosystem services increases for all livelihood types in the regionally-connected, agriculturally-dominated scenario, and decreases in the regionally-connected, economically-diverse scenario. Resilience to likely development trends can be explored by examining scenario changes in livelihoods and ecosystem service dependencies. These explorations of resilience should be useful in strategic planning in the study area, and may provide models useful to planning elsewhere.

Résumé

Les humains tirent de nombreux avantages de la nature. Ces avantages sont souvent appelés services écosystémiques et incluent l'eau notamment fraîche, la nourriture, le carburant, la formation des sols, les possibilités de loisirs et la régulation du climat, parmi tant d'autres. Les changements dans les services écosystémiques futurs sont incertains à cause de nombreux facteurs anthropogènes et non anthropogènes. Dans les pays en développement, les populations rurales dépendent largement des services écosystémiques pour gagner leur vie, obtenir de la nourriture, du carburant, des revenus, et répondre à leurs besoins médicaux. Les populations rurales dépendent souvent des ressources naturelles offertes par leur environnement. À l'avenir, par conséquent, les changements dans la qualité ou la disponibilité des services écosystémiques auront les conséquences les plus immédiates et graves sur les populations rurales. Prévoir pour l'avenir représente donc un défi dans le contexte des systèmes socio-écologiques, à cause des interactions dans le temps et l'espace, des questions de politiques et des incertitudes concernant le développement. À cause de la complexité des systèmes socio-écologiques, il est également difficile de prévoir comment les modifications du paysage pourraient éventuellement affecter les services écosystémiques et, par la suite, ceux qui dépendent de ceux-ci pour leur bien-être. La planification de scénarios est une méthode participative stratégique pour étudier les trajectoires de développement futur possibles dans vingt à cinquante ans. Elle peut être utilisée pour se préparer aux changements rapides, inattendus ou mal compris dans les services écosystémiques. L'objectif principal de cette recherche est d'utiliser la planification de scénarios pour étudier les

changements plausibles dans la dépendance future aux services écosystémiques dans le bassin versant de Miyun, situé dans le nord de la Chine. Afin d'y parvenir, cette recherche doit d'abord mener des exercices régionaux de planification de scénarios dans un groupe témoin de trois villages. Elle s'attarde ensuite à la réponse sous-régionale aux scénarios régionaux sur les perspectives plausibles de développement futur. La littérature sur les méthodes de planification de scénarios et les découvertes se concentrent sur la création de scénarios et les descriptions de l'avenir. L'approche présentée au Chapitre 3 va plus loin en sollicitant une réponse sous-régionale aux scénarios et aux processus d'apprentissage que les villages peuvent adopter afin d'atteindre les futurs des scénarios. Le Chapitre 4 utilise les résultats de scénarios contradictoires pour explorer les changements futurs possibles dans la dépendance aux services écosystémiques du groupe témoin de trois villages. La mesure dans laquelle les populations rurales des pays en développement dépendent des services écosystémiques est inconnue et les méthodes pour répondre à cette question se développent dans la littérature. Dans le Chapitre 4, la recherche explore les changements des scénarios dans la dépendance aux services écosystémiques des populations rurales et cherche à comprendre la vulnérabilité des moyens de subsistance en tant que résultat des changements plausibles dans les services écosystémiques. Les conclusions montrent que les villages du groupe témoin diffèrent dans les procédés utilisés pour atteindre les futurs des scénarios régionaux. Cette recherche reflète la documentation sur la cogestion adaptative et souligne l'importance de comprendre la diversité dans la réponse régionale afin d'atteindre les buts régionaux concernant les politiques. Ensuite, les scénarios ont été comparés aux mesures de base sur la dépendance aux services écosystémiques des activités économiques des villages et des mesures plausibles sur la dépendance économique future aux services écosystémiques ont été déterminées. Les résultats montrent que la dépendance aux services écosystémiques augmente pour tous les types de moyens d'existence dans le scénario de dépendance agricole et diminue pour le scénario régional à diversité économique. La résistance aux tendances du développement possible peut être explorée en étudiant les changements de scénarios concernant les moyens de subsistance et la dépendance aux services écosystémiques.

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Contribution of Authors

Rachel Maynard wrote Chapter 1. Brian Robinson and Thom Meredith provided comments and revisions to Chapter 1. Rachel Maynard wrote Chapter 2. Brian Robinson and Thom Meredith provided comments and revisions to Chapter 2. For Chapters 3 and 4 Rachel Maynard and Brian Robinson designed research; Rachel Maynard, Brian Robinson, Hua Zheng, Sai Ma, Wenjia Peng, developed workshop strategies, Rachel Maynard, Brian Robinson, Sai Ma, Wenjia Peng, and Binbin Huang conducted workshops; Rachel Maynard analyzed data. Rachel Maynard wrote Chapter 5. Brian Robinson and Thom Meredith provided comments and revisions to Chapter 5.

Chapter 1. Introduction

Ecosystem services are the benefits people receive from nature either directly or indirectly (Daily 1997). The future of ecosystem services is uncertain (Bohensky et al., 2006, Alcamo and Henerichs 2008, Carpenter et al., 2015) as a result of various factors including rapid population growth and technological change (Biggs et al., 2010). Rural populations are typically directly dependent on ecosystem services for a wide variety of benefits including livelihoods, food, fuel, health, income and employment (Ellis 2000, Alcamo et al., 2005, MA 2005, Vedeld et al., 2007, Daily et al., 2009, Tieguhong and Nkamgnia 2012). The direct dependence on local ecosystem services is greater for rural populations than for urban populations, and so their vulnerability to local environmental change is likewise more acute (Cumming et al., 2014). Due to the high levels of uncertainty surrounding the future of ecosystem services and the strong connections between rural populations and ecosystem services, it is necessary to examine rural people's response to plausible future changes in ecosystem services.

A major challenge is anticipating how future development may impact landscapes and the various interactions of social-ecological systems in the rural areas of developing countries. This challenge is important to address because development may affect ecosystem services in rural areas and, ultimately, affect the level of dependency people have on future available resources and their overall well-being and livelihood resilience (Carpenter et al., 2015, Yang et al., 2013). This thesis addresses these challenges by examining rural population response to plausible future changes in ecosystem services in three villages of the Miyun watershed, China. The Miyun watershed is about 100 km north of Beijing and the Miyun reservoir provides Beijing with approximately 75% of its total freshwater drinking supply (Kröger et al., 2012). The three study villages were selected for study because each is distinct with respect to location, climate, socioeconomic condition, dominant livelihood strategies and skillsets.

1.1 Objectives

The objective of this project is to understand how future development trajectories may alter local environments and thereby impact local vulnerability to changes in ecosystem services. The main objectives were explored explicitly in Chapters 3 and 4 of this thesis (Chapter 1 is the introduction; Chapter 2 is a literature review):

Chapter 3 objective:

- Examine sub-regional responses to regional scenario futures and reflect on possible adaptive co-management strategies. Specific objectives include (i) understand regional drivers of change, (ii) develop regional scenarios, and (iii) link sub-regional responses to regional scenario futures. Sub-regional responses are of interest here in order to learn plausible adaptive co-management responses to scenario changes.

Chapter 4 objective:

- Assess the implications of these future scenarios for direct reliance on local ecosystem services. Specific objectives include (i) understand baseline livelihood ecosystem service dependencies from a previously conducted household survey, (ii) connect baseline measures with livelihood type changes from the village scenario planning exercises and (iii) estimate plausible future changes in livelihood activities and corresponding changes in ecosystem service dependencies.

The scenario planning exercises in the three study villages are conducted in order to learn possible regional future development trajectories and the specific processes a village might engage in to reach those scenario futures. Following the creation of the scenario storylines, the study specifically asked:

- What livelihood strategies might communities engage in in the future?
- What plausible risks are communities facing and what adaptive changes might they reasonably take to minimize negative consequences of alternative future regional scenarios?
- How might changes in ecosystem service dependency make populations more or less resilient to future development trajectories?

In developing countries, rural populations are strongly connected to their landscape; they depend upon local resources for food, fuel, income and employment. The study of rural population’s response to plausible future development trajectories can help to better prepare for unexpected changes in the quality or quantity of ecosystem services. This study is intended to help identify adaptive responses for the study villages, but also to help advance research in methods that can be effective in identifying strategic responses to local threats to ecosystem services and people's associated dependency on ecosystem services.

1.2 Policy relevance

The sub-regional responses to plausible regional development scenarios can inform policy-makers on the strengths and opportunities for improvement in each region (i.e. skillsets, climatic, soil quality or water resource availability and quality limitations, etc.). Implementation of adaptive co-management strategies can help to ensure that sub-regional responses to regional development scenarios are considered alongside the interests of various stakeholders, the policy needs of regional governments, and the economic development goals of businesses.

Future ecosystem service dependency measures might reveal possible livelihood types which may be vulnerable to scenario development trajectories. Chapter 4 uses baseline ecosystem service dependency of livelihood types from the study region and scenario changes in livelihoods from scenarios to learn plausible future livelihood ecosystem service dependencies. Changes in dependency may correspond with certain development pathways. For example, dependency on ecosystem services may increase in agriculturally dominated scenarios. From this information, targeted policies can be created to protect the resources on which people depend in the present, and those on which they may come to depend as according to any given plausible scenario development trajectory.

1.3 Structure of the thesis

This is a manuscript-based thesis. Chapter 1 introduces the research Chapter 2 presents a review of the literature covering ecosystem services, social-ecological systems, sustainable livelihood framework, ecosystem service dependency, scenario planning, adaptive co-management and resilience. The first manuscript is presented in Chapter 3 which describes the scenario planning exercises in detail, presents a new poly-workshop approach to scenario planning and discusses adaptive co-management strategies using outcome of the scenario poly-workshops. The second manuscript is presented in Chapter 4 which explores future ecosystem service dependency measures using the livelihood changes found from the scenario planning poly-workshops and examines livelihood resilience in response to changes in dependence on ecosystem services.

Chapter 5 reviews all findings, discusses the implications of the findings for policy, discusses how this work can inform future research, and states remaining questions. Appendices and short descriptions of the appendices can be found following the references section.

Chapter 2. Literature Review

2.1 Introduction

This project draws on several bodies of literature, as outlined in this paragraph. Each is treated in detail in the sections below. The ecosystem services are the benefits humans receive from nature (Daily 1997); this literature is foundational to understanding the contribution of ecosystem services to people's livelihoods and well-being. The approach to study of the complex interactions between people and their environment is referred to as social-ecological systems approach. An example of social-ecological systems research topic may be the study of water quality in a region where agricultural production contributes to algal blooms in an area used for recreation and threatened or endangered species. The sustainable livelihood framework, presented by Scoones (1998), describes the five capitals which contribute to a sustainable livelihood; to highlight its relevance, natural capital and social capital are two of the five capitals. Ecosystem service dependency is an emerging body of literature which focuses on measuring the level of dependence a household, individual or community is on natural resources. This study uses scenario planning methodology to learn plausible future developments in the Miyun watershed. Scenario planning is a qualitative approach to explore future uncertainty of regional drivers of change. The narratives developed as a result of scenario planning workshops can help to prepare decision-makers for future surprises in development, the economy, population or ecosystem services (Postma and Liebl 2005, Van't Klooster and van Asselt 2006, Enfors et al., 2008, Carpenter et al., 2015). The adaptive co-management literature is examined here because it is a more holistic approach to policy creation than a single-party decision-making approach. Scenario planning uses many stakeholders to create the scenarios thus, the inclusion of adaptive co-management as a strategy to develop and enforce policies is logical connection. Changes in livelihood ecosystem service dependency can inform on plausible future livelihood resilience responses. Resilience is the capacity to adapt to shocks and still maintain baseline functions (Folke 2006); resilience literature is examined in relation to livelihood resilience to scenario changes in ecosystem services.

2.2 Ecosystem services

Ecosystem services are defined as the direct or indirect benefits humans receive from nature (Daily 1997, Fisher et al., 2009). Ecosystem services are grouped into four main categories as defined by the Millennium Ecosystem Assessment (2003), provisioning, regulating, cultural and supporting services. Provisioning services include food, fuel, fiber and freshwater. Regulating services include climate regulation, erosion control, and human disease regulation. Cultural services include recreation, and aesthetic experiences. Lastly, supporting services include soil formation, primary production and oxygen production. Many people depend upon ecosystem services for their livelihoods, employment, food, fuel, or medicinal and cultural needs. In general, the poor are more dependent on ecosystem services and therefore, are more vulnerable to ecosystem service decline or degradation (Yang et al., 2013). Measuring household ecosystem service dependency is a relatively new concept in ecosystem services literature (Vedeld et al., 2007, Angelsen et al., 2014) but understanding the extent to which people are dependent upon and utilize ecosystem services is relevant to all development and sustainability initiatives.

The ecosystem services literature predominantly takes a perspective of a cascading relationship in which people benefit from flows that come from ecosystem services (Haines-Young and Potschin 2010). However other literatures, such as those that operate within a “social-ecological systems” framework, more explicitly recognize the feedbacks and synergies between ecosystems, the benefits people receive from nature, and the governance of these feedbacks.

2.3 Social-ecological systems

Social-ecological systems (SESs) are integrated, coupled systems of humans and their environment (Holling 2001, Armitage et al., 2009). Olsson et al. (2004) note the main features of social-ecological systems are change and uncertainty. In detail, SESs are the complex relationships between resource systems, resource units, institutions, and users of ecosystems (Ostrom 2009). Ostrom refers to the above as subsystems within the SES. She notes the subsystems must also be examined further by examining these relationships at different spatial and temporal scales. For example, the spatial scales of a resource system such as a forest may vary between two different SESs. Further, a resource unit may be the same in two different SESs but vary in unit price. The scales of subsystems within SESs are important to consider during research efforts but also contribute to the complexity of the system. The consideration of spatial and temporal scale within SESs is referred to by Holling (2001) as the panarchy. Much of the SES literature stresses the importance of embracing the system's complexity and uncertainty and the need to analyze subsets of interactions within the system (Holling 2001, Ostrom 2009).

The components of a SES can be examined independently but upon interaction they produce outcomes which may be complex and uncertain. This makes analysis of SES outcomes difficult (Holling 2001, Ostrom 2009). Ostrom's (2009) framework provides guidance to answer SES questions such as "Why are the pollution levels in some lakes worse than others?" Or, "why do some locally managed forest thrive better than government-protected forests?" (Ostrom 2009).

As noted above social-ecological systems are complex within themselves but it is also necessary to examine feedbacks and tradeoffs between other relevant SESs. Social-ecological systems (SESs) are linked to external local social, economic and political settings and larger related ecosystems such as climate and pollution patterns (Ostrom 2009).

Human actions typically dominate the outcomes of SESs (Folke 2006) .Individuals who make decisions regarding SESs often consider social, institutional and biophysical factors (McGinnis and Ostrom 2014). Examples of human impacts on SESs include overfishing, reduction of biological diversity, accumulation of nutrients, and soil erosion (Folke 2006). The outcomes of social decisions can affect the adaptability and resilience of the system (Folke 2006). Further, less desirable states of SESs have negative impacts on livelihoods and societal development (Folke 2006).

Social-ecological systems research studies interaction of humans and their environment over time and space and considers specific locational contexts (i.e. policy, climate, socioeconomic). In order to improve ecosystems using the SES approach many areas need to be studied as a system with feedbacks and inputs and outcomes. The sustainable livelihood framework is often used as a method to systematically examine a SES.

2.4 Sustainable livelihood framework

The focus of this work is to examine how livelihoods might change as a result of plausible future regional development scenarios. In order to accomplish this, an understanding of the foundations of sustainable rural livelihoods is needed. Scoones' (1998) sustainable livelihoods framework is central to this understanding; his framework examines the contexts, livelihood resources (i.e. types of capital), livelihood strategies and institutional process present in order investigate the outcomes of achieving or worsening sustainable rural livelihoods (Chambers and Conway 1992). Using Scoones' framework, sustainable livelihood outcomes can be examined at different scales (i.e. individual, household, village region or nation).

The types of five capital people draw upon for their livelihoods and listed in the sustainable livelihoods framework are natural capital, financial capital, human capital, and social capital (Scoones 1998). The specific resources of each capital vary depending on the specific contexts of a research question. Natural capital includes the natural resources a household uses such as timber, genetic resources, freshwater, soil formation. Natural capital resources can also be referred to as ecosystem services from which households use for their livelihood strategies. Financial capital includes income, savings, credit, and assets. Scoones (1998) includes infrastructure, equipment and technologies in financial capital while Ellis (2000) presents a fifth category of capital; physical capital which includes roads and irrigation. This project uses five capitals and includes production equipment and technologies as household assets within financial capital and physical capital includes infrastructures such as roads, communication networks, and irrigation. Human capital includes skillsets, knowledge, and health. Social capital includes social networks, equity, and relationships (Bebbington 1999, de Haan and Zoomers 2005).

While livelihoods can be considered separate from human well-being, the two are interconnected (Scoones 1998) and therefore a brief discussion on human well-being seems appropriate. Human well-being includes many components listed within the sustainable livelihoods framework. The main objective of the Millennium Ecosystem Assessment (2005) (MA) is to examine how changes in ecosystem services affect human well-being. The MA (2005) includes "secure livelihood" in their definition of human well-being; other items include clean water and air, food, shelter, access to goods, health, good social relations, education, and equity. Scoones (1998) and other scholars agree, well-being encompasses more than human capital, food or income (Bebbington 1999). From this, we can infer well-being can change independently of a person's livelihood and a person's livelihood could change while well-being may not. Further, a loss of a person's livelihood could affect their well-being but a decrease in a person's well-being may not affect their livelihood. While well-being was not specifically addressed in this study, the importance of its consideration and connectedness to livelihoods is important.

The level of overall dependency on ecosystem services may shift in accordance with the types of ecosystem services households are dependent upon for their livelihoods (Ellis 2000, MA 2005, Vedeld et al., 2007, Tieguhong and Nkamgnia 2012, Yang et al., 2013). Often rural households have diverse livelihood strategies and therefore are dependent on more than one ecosystem service. By categorizing households by dominant livelihood activity, it is possible to learn the levels of ecosystem service dependency associated with each type of livelihood activity. Livelihood type ecosystem service dependency measures provides a new approach to examine household dependency measures. The ecosystem service dependency literature review revealed that ecosystem service dependency is typically explored in relation to socio-economic status, not main livelihood activity.

The sustainable livelihood framework examines the resources people need in order to achieve or sustain a sustainable livelihood. Ecosystem service dependency literature compliments this by examining specifically the ecosystem services which contribute to a person's livelihood. It goes a step further than providing a framework by describing methodology to calculate dependency on resources. Understanding the level of dependence on ecosystem services is very helpful to natural resource management efforts.

2.5 What is ecosystem service dependency?

Ecosystem service dependency is a relatively new topic in ecosystem services literature. There is a need to quantify human dependence on ecosystem services to help better understand social-ecological relationships (Yang et al., 2013). In order to address this need, concepts of ecosystem service dependency are developing within the ecosystem services literature (Yang et al., 2013, Robinson, in preparation). Many of the ideas for the developing concepts related to ecosystem service dependency originate from forest income dependency studies (e.g. Angelsen et al., 2014, Vedeld et al., 2007). Vedeld et al. (2007) use the ratio of a household's income relative to forest income in order to calculate household forest dependence. However, household forest dependence is interpreted as a household's dependence on income from forest activities in relation to a household's income from all other livelihood activities. This interpretation does not fully capture dependence on ecosystem services for two reasons. First, households are dependent on ecosystem services for more than just income. As stated above people can be dependent on ecosystem services for employment, medicine, additional food sources, fuel, and other cultural or recreational activities.

In a recent study, Yang et al. (2013) define ecosystem service dependency as the "ratio of the net benefits obtained from ecosystems to the absolute value of total net benefits from ecosystems and other socioeconomic activities". However, Yang et al. (2013) do not calculate the benefit from nature specifically; they use agricultural revenue as the ecosystem service value. There is still more work to be done in the ecosystem service dependency field to quantify the benefits people receive from nature. Ecosystem service dependency aims to quantify social-ecological relationships by examining the net benefits humans receive from nature in relation to the total benefits they receive from their livelihood strategies.

2.5.1 How is ecosystem service dependency measured?

As stated above, ecosystem service dependency literature stems from the forest income dependency research. Forest income is calculated by first determining net household income. Household products consumed and sold at market price are included in gross income measurements (Mamo et al., 2007, Tieguhong and Nkamgnia 2012). Next, expenditures, fines and damages by wildlife were deducted from gross income (Sjaastad et al., 2005, Mamo et al., 2007, Tieguhong and Nkamgnia 2012). Total household income is then compared to total forest income (Vedeld et al., 2007). The share of forest income relative to total income is considered the level of resource dependency (Vedeld et al., 2007). High dependence on ecosystem services may lead to high vulnerability to declines in corresponding ecosystem services (Yang et al., 2013).

2.5.2 Categorizing household livelihoods

As stated above, ecosystem service dependency concepts are based on forest income dependency literature which typically reports forest income dependency findings by household income levels. In order to calculate ecosystem service dependency by livelihood type, households must first be categorized by main livelihood type. Livelihood strategy surveys can answer questions relevant to household ecosystem service dependency measures. Using Robinson's (in preparation) dataset, ecosystem service dependency can be determined by livelihood activity rather than income level. The results may provide additional information on dependencies certain livelihood types may have on ecosystem services when compared to other livelihood types. These findings may guide the focus of decision-makers towards sectors of industry rather than household income-based pathways.

The values of people's dependency on ecosystem services can then be used alongside scenario planning exercises. Scenario planning is used as a method to explore plausible future changes in ecosystem services; therefore applying scenario results to plausible dependency measures is rational. Scenario planning as an approach to explore future livelihood dependency measures is appropriate because of the method's applicability, systematic approach and participatory involvement of local user groups.

2.6 Scenario planning

Scenario planning is a tool to understand and manage uncertainty in decision-making processes (Bohensky et al., 2006). Scenario planning's main contribution to studies about the future is its consideration of uncertainty in a systematic way (MA 2005). Scenarios are plausible narratives about the future which consider past drivers of change, existing conditions, and future drivers of development which are considered to be uncertain (Goodwin and Wright 2001, Postma and Liebl 2005, Van't Klooster and van Asselt 2006, Enfors et al., 2008, Carpenter et al., 2015). Scenarios are neither forecasts nor predictions but are developed to be plausible accounts of the future (MA 2005, Whitfield and Reed 2012). Scenarios are typically developed to cover a period of ten to fifty years into the future (IPCC 2013, MA 2005, Peterson et al., 2003, van Vliet et al., 2010). Scenarios are useful for future land management decision-making and have been used historically by the business, military and science sectors (Van't Klooster and van Asselt 2006, Patel et al., 2007, Malinga et al., 2013).

A well-known business application of improved decision-making as a result of scenario planning is the case of the Royal Dutch Shell Corporation. Drivers of change external to the corporation (i.e. market incentives, community and regulations) explored in a scenario planning exercise and the management team left the process in better positions than their competitors to handle shocks in oil prices (Glenn 2006). Scenario planning's application in policy can be seen in the Mont Fleur scenarios where the process resulted in an enrichment of negotiation during South Africa's transition to democracy (Peterson et al., 2003, Scholes and Biggs 2004). Goldstein et al. (2012) highlight the complexity of future decision-making in interface of economic, legal and cultural considerations. In decision-making which involves ecosystem services, discussing trade-offs with stakeholders provides an opportunity to inform them on how the result of certain decisions may affect future sustainability initiatives (Goldstein et al., 2012).

In general, the aim of most scenario planning exercises is to promote social learning, collaboration, and adaptive response to shocks or surprises (Patel et al., 2007, Enfors et al., 2008, Malinga et al., 2013). Stakeholders involved in a scenario planning exercise conducted in the Kilimanjaro region of Tanzania included farmers, village chairmen, a non-governmental organization (NGO) representative and a representative of the District Council (Enfors et al., 2008). That study showed that small scale water systems were considered valuable regardless of scenario (Enfors et al., 2008). They stress a systems approach to making future decisions and highlight the importance of building capacity among farmers and involving diverse sets of collaborators (Enfors et al., 2008). Scenario planning exercises can result in improved applied decision-making when similar trends are seen among alternative scenarios, thereby identifying high-likelihood outcomes, or when the process builds consensus among a diverse set of stakeholders, thereby helping to coordinate responses.

2.6.1 Participatory approaches in scenario planning

Scenario planning is a participatory systematic approach to examine complex futures and prepare for surprises (Enfors et al., 2008, Malinga et al., 2013). The level of stakeholder participation varies with each study but it is common for stakeholders to be involved in the scenario planning process at every step (Patel et al., 2007, Enfors et al., 2008, Quinlan 2012, Malinga et al., 2013, Carpenter et al., 2015).

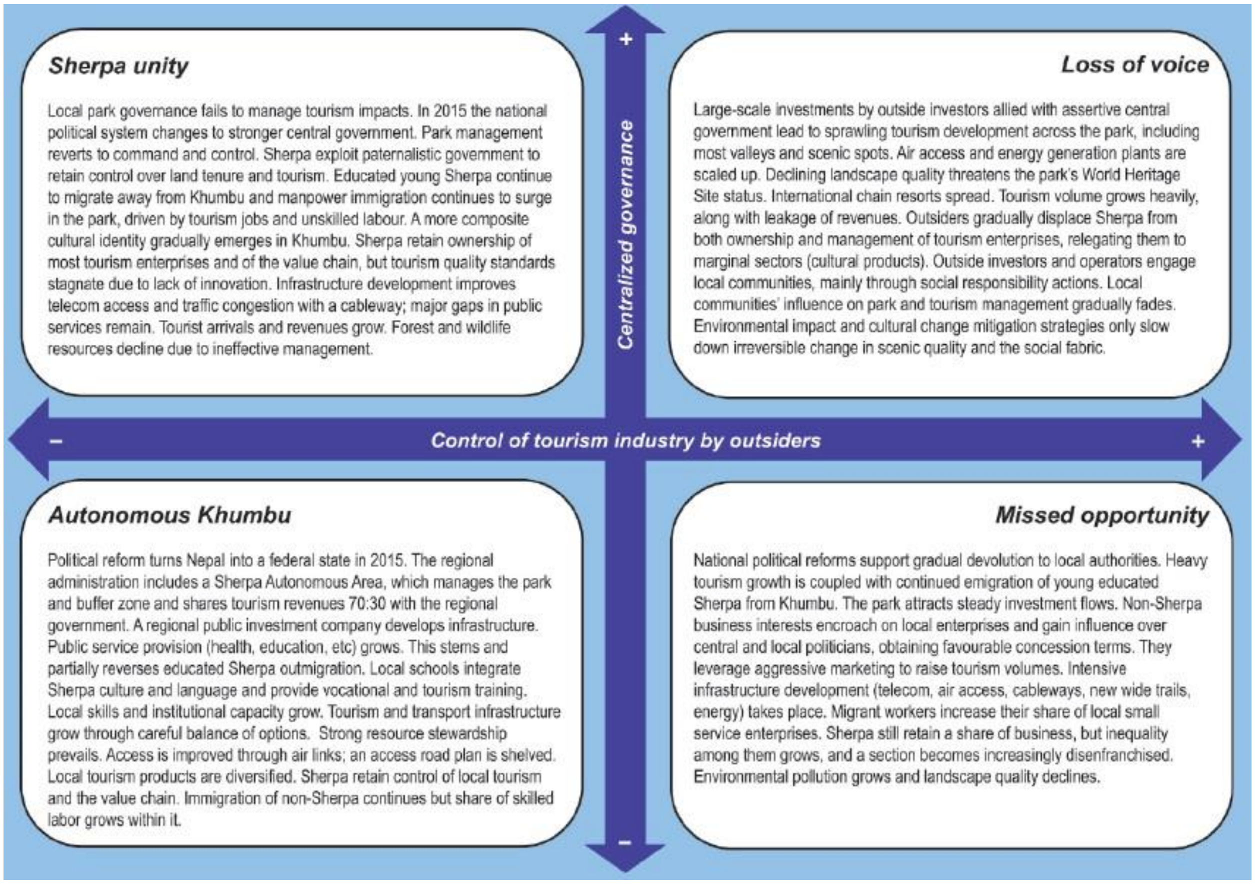
In scenario planning workshops, facilitators typically lead the group of stakeholders in activities for developing the scenarios. Workshops can begin with a visualization exercise where participants are asked to think back 20 to 50 years or sometimes farther back in history and are prompted with questions from the facilitators regarding the changes they have experienced (Evans et al., 2006).

Commonly, the next step in the scenario planning exercises would be to determine the two most important and uncertain drivers of change in order to create what are called scenario axes diagrams (Van't Klooster and van Asselt 2006, Quinlan 2012). Stakeholders are asked to think of five to ten drivers of change which have been important or notable catalysts of changing the landscape in the past (Van't Klooster and van Asselt 2006, Daconto and Sherpa 2010, Quinlan 2012). From this list, participants are then asked which of those drivers of change have the most consequential outcome, and which have the least certain outcome (Postma and Liebl 2005, Evans et al., 2006, Enfors et al., 2008, Quinlan 2012). Participants are given two stickers and are asked to pick two drivers of change from the list of five to ten drivers of change which they think are the most important (Quinlan 2012). The same is done for drivers of change which they consider uncertain. The result is a list of drivers of change which are ranked by importance and uncertainty.

Facilitators then build a discussion with the participants on the plausible trajectories of the highest ranked drivers of change. The drivers of change considered to be most important and most uncertain are then incorporated into the scenario planning narratives (Quinlan 2012). Selecting the most important and uncertain drivers of change is the crux of the scenario planning exercise. Drivers which have been notable catalysts of change in the past contribute to the plausibility of the final scenarios. Selecting uncertain drivers of change makes the scenarios interesting for discussion of future development trajectories and allows for the preparation of plausible surprising future events.

The two most important and uncertain drivers of change are selected from the ranked list. Next, the research team discusses and decides on two distinct trajectories for each final driver of change. For example, in an ecotourism scenario planning exercise the two selected drivers of change were centralized governance and control of tourism industry by outsiders (Dacanto and Sherpa 2010). In general, the centralized governance axis ranges from a strong centralized government to a weak centralized governance and the control of tourism industry by outsiders' axis ranges from very controlled by outsiders to mainly controlled by locals involved in the tourism industry. Each driver of change is placed on an axis and the distinct trajectories of each driver of change are placed on each end of the axes (Figure 1).

Figure 1: Example of a scenario axes diagram (Daconto and Sherpa 2010)



The research team then develops plausible future conditions of each scenario which corresponds to the parameters set up in each quadrant. For example, in a strong centralized governance and highly controlled tourism industry by outsiders scenario, (Figure 1 *Loss of* Voice) the tourism industry expands across landscapes it hasn't in the past and the outsiders marginalize the local tourism workforce and as a result their influence in management decisions fade. After the conditions of each scenario are discussed and agreed upon by the research team, the scenarios are then elaborated and communicated to the stakeholders in appropriate ways.

Additional steps to scenario storyline development may include the creation of scenario illustrations for efficient communication of final scenarios. During the scenario planning exercises Enfors et al. (2008) use illustrations to communicate the Makanya scenarios to the local people. Quinlan (2012) worked with a local artist to develop illustrations which represent the developed scenarios of the Bonnechere River Watershed. Once the scenarios are developed, the team gathers feedback from the participants on the storylines, illustrations and other materials and makes changes to the scenarios based on the feedback (Evans et al., 2006, Enfors et al., 2008, Quinlan 2012, Malinga et al., 2013, Carpenter et al., 2015).

2.6.2 Representation in scenario building

The dominant workshop scenario planning method gathers regional stakeholders who are typically leaders in their field (i.e. policy leaders, business managers, scientists, NGOs) to a central location within the region (Carpenter et al., 2015). The method of meeting in a central location is referred to as the centralized-workshop method. Typically, two workshops are needed to complete the scenario planning exercise (Patel et al., 2007, Daconto and Sherpa 2010, Carpenter et al., 2015).

The question of whether to include both urban and rural stakeholders is dependent on the research questions the study aims to answer and what the scenarios are going to be used for following the exercises (i.e. land use planning, policy decision-making, social learning) (Patel et al., 2007). It may be difficult or seen as not worthwhile for smallholders to travel to central locations. For this reason, and others, smallholder voices are under-represented in regional decision-making conversations (Scholes and Biggs 2004, Foley et al., 2005, Woods 2012). Further, in regards to land use change, even within one rural region there are many drivers behind rural land use decisions therefore, within-community response can be very diverse (Brondízo et al., 2002). The same driving factors may lead to a different result at different locations because locations have differences in contexts and characteristics (Verburg et al., 2010). The drivers of change which affect urban residents are intrinsically different than drivers which affect rural populations. Rural areas differ in economy, infrastructure, landscape, culture, demography and other factors compared to urban areas (Ghelfi and Parker 1997), so blending urban and rural populations in a single workshop may be counterproductive. A scenario planning exercise involving a majority of stakeholders residing in urban areas may bias the scenario narrative towards one which favors urban drivers of change and disregards rural changes in development.

Significant differences between drivers of change in rural areas and drivers of change in urban areas further enhances the need to study sub-regional local response to regionally shared visions of the future. The centralized-workshop scenario planning approach to regional decision-making can be further improved by vising sub-regional locations and engaging smallholders in studies about the future and decision-making conversations. A poly-workshop approach to scenario planning where workshops are held in rural sub-regions may better include rural livelihood perspectives on current rural conditions, drivers of change, and processes to achieve future scenario states.

2.7 Adaptive co-management

Decision-makers face a multitude of challenges including the proper incorporation of cultural considerations, social and ecological assumptions of stability, and expert and scientific certainty on relevant topics (Walker et al., 2004, Armitage et al., 2009). Armitage et al. (2009) state, ecological and social uncertainty is "…inherent to governance, and is best addressed with collaborative processes and multiple sources and types of knowledge". Adaptive management is an iterative, continually evaluated process where managing and learning about natural resources occurs simultaneously (Williams 2011). Adaptive management strategies should be altered to meet changing needs (Nelson et al., 2007). This process can be informed by science or local and traditional knowledge systems (Berkes et al., 2000, Nelson et al., 2007).

Adaptive management differs from adaptive co-management in that the latter incorporates the ideas from a diverse set of actors from local to national organizations into decision-making (Olsson et al., 2004). Adaptive co-management is a collaborative approach to natural resource management which combines the ideas of co-management and adaptive management (Armitage et al., 2009). Adaptive co-management is flexible in its approach to resource management and has the ability to actively engage many actors in the decision making processes (Armitage et al., 2009). Stakeholders share ideas and knowledge in an open setting designed to build trust and promote social learning (Olsson et al., 2004, Armitage et al., 2009).

The key strengths of the adaptive co-management approach are (i) it is tailored to specific places and situations and (ii) there is an emphasis on the role of local-level actors in the decision-making process (Armitage et al., 2009). Adaptive co-management considers the specific contexts of ecosystems, institutional settings, socio-economic conditions and livelihood outcomes during the collaborative process (Armitage et al., 2009). The local-level users of ecosystem services contribute relevant knowledge of the current ecological conditions and past events (Malinga et al., 2013, Patel et al., 2007, Whitfield and Reed 2012). The social learning and shared knowledge initiatives promoted within the network of stakeholders contributes to trust-building and successful monitoring of decision-making outcomes (Armitage et al., 2009).

In order for the decisions made during the adaptive co-management sessions to transfer to tangible policies, the policy environments must be supportive of the stakeholder networks created (Armitage et al., 2009). Armitage et al. (2009) state, policymakers must reward scientists and mangers for participating and for successful implementation of the policy, it is important to enforce the monitoring procedures. They warn, if certain components of the adaptive co management system are missing from the process, the sustainability and resilience of social-ecological systems may suffer (Armitage et al., 2009).

Scenario planning is a useful tool for exploring future development uncertainty and planning for surprises. Changes in ecosystem services can impact rural populations' livelihoods and affect their livelihood resiliency. Understanding plausible future changes in ecosystem services, as a result of possible development, can help to inform on the future resilience of rural population livelihoods.

2.8 Resilience

Resilience concepts are applied to many sub-disciplines of the social-ecological systems field. Ideas of resilience center on "non-linear dynamics, thresholds, uncertainty and surprise" and how these dynamics interact across space and time (Folke 2006). Folke (2006) defines resilience as the "capacity to absorb shocks and still maintain function and capacity for renewal, re-organization and development".

Resilience concepts are used in this work to examine livelihood resilience to possible development changes in the Miyun watershed, China. Adger (2000) defines social resilience as a "group or community's ability to cope with external stresses or disturbances as a result of social, political or environmental change". Tanner et al. (2015) add that livelihood resilience is the capacity to "sustain and improve their livelihood opportunities… despite environmental economic, social and political disturbances". By use of scenario planning, this study examines plausible future development changes and the effects on livelihoods and ecosystem service dependency. The livelihood changes as a result of the scenario planning exercises allow for the examination of livelihood resilience to plausible future scenarios.

Adger (2000) highlights the link between social and ecological resilience. This link is strong because communities are dependent on environmental resources for their livelihoods (Adger 2000). Adger (2000) poses the question: are social and ecological resiliencies separable while studying livelihood resilience; in other terms, are livelihoods considered resilient on their own merit or are they resilient because the ecosystems they depend upon are resilient? This question, while difficult to answer, is central to livelihoods resilience research.

Frameworks to assess resilience have been developed in order to complete empirical analyses on SES (Ostrom 2009) and livelihood (Walker et al., 2004, Silva et al., 2010, Speranza et al., 2014) resilience. While this thesis does reflect on livelihood resilience to plausible development changes, it does not assess plausible resilience of the study communities. This paper examines livelihood resilience to plausible scenario shifts in the supply of ecosystem services. The scenarios created provide alternate worlds where it is possible to explore shifts in livelihood strategies as a result of likely development trends. In addition, it's possible to learn how ecosystem service dependencies of livelihood types may change in the plausible future scenarios.

Chapter 3. Divergent scenario futures of three villages in the Miyun watershed, China[1]

3.1 Abstract

Recent policy changes in the Miyun watershed, China have contributed to dramatic shifts in land use, livelihood types and economic activities (Regele 2008, Zheng et al., 2013). The Miyun watershed is under protection to improve water quality and quantity for the population of Beijing (approximately 20 million). The future of ecosystem services is uncertain due to rapid changes in human population, policies, technology, and land use practices (Biggs et al., 2010). A challenge is planning for the future in the context of social-ecological systems because of interactions over time and space, policy considerations, and development uncertainties. Scenario planning is commonly used to explore future uncertainty of ecosystem services over time and space. It is a systematic approach to exploring plausible futures of a region. The centralized-workshop scenario method typically brings regional stakeholders together to create collective visions of the future. Sub-regional variation and local responses to scenarios are seldom examined. Using the participatory scenario axes approach, we address this gap by first developing four scenarios with the participation of three different villages in the Miyun watershed. Divers of change were collected from the villages and synthesized to create four scenarios that represent common drivers affecting the whole watershed. Next, we worked with stakeholders from each of our three study villages to create village-specific scenario storylines using the same general scenarios but allowed the scenario outcomes to vary in each village. We found a diversity of responses to how each of the scenario storylines develop over the next 20 years in each village. Effective and equitable land use planning and social policy must recognize this sub-regional diversity and the distribution of responses to common drivers of change.

3.2 Introduction

Globally, many ecosystem services are in decline, such that their future availability and quality is uncertain (MA 2005). Rapid population growth and technological advancements add to the uncertainty of how social-ecological systems may respond to these changes (Biggs et al., 2010). Changes in natural resources increasingly affect rural populations who depend upon them for their incomes (Ellis 2000, MA 2005, Woods 2012, Mamo et al., 2007, Vedeld et al., 2007).

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[1] This chapter is intended to be submitted as manuscript for a scientific journal.

Current scientific literature examines the value of ecosystem services to society and how people depend on ecosystem services for livelihoods (Angelsen et al., 2014, Zenteno et al., 2012). However, a main challenge is how to understand the way future landscape changes may affect ecosystem services and, in turn, affect those who depend on these services for their well-being (Carpenter et al., 2015, Yang et al., 2013).

Predicting future landscapes is often accomplished with economic or land use modelling (Jantz et al., 2004, Ligtenberg et al., 2001) or more qualitative and participatory scenario planning (Patel et al., 2007). Scenario planning is one tool that can be used to explore future states (Star et al., 2016) and has the advantage of incorporating shocks and surprises which might not have been included otherwise in a regional decision-making process (Peterson et al., 2003, German et al., 2009). The participatory process brings together people from different stakeholder groups (i.e. businesses, scientists, government etc.) to build consensus and explore new horizons of the future concerning a focal topic (Whitfield and Reed 2012, Malinga et al., 2013). Typically, regional stakeholders attend scenario planning workshops held in a central location, which we refer to as the centralized-workshop scenario planning approach (Patel et al., 2007, Daconto and Sherpa 2010, Carpenter et al., 2015).

However, landscapes have intrinsic heterogeneity in climate, social structure, economic productivity, biodiversity, infrastructure, and population characteristics. Rural populations may gain more from regional scenario planning if sub-regional rural responses are considered during the scenario planning process. Changes in social-ecological systems are unpredictable and therefore, rural populations whose livelihoods are closely linked to ecosystems services and are sensitive to landscape changes (Whitfield and Reed 2012) should be more frequently and actively involved in rural land management decision-making.

The objectives of this thesis are to examine sub-regional response to regional future scenarios of the Miyun Watershed, China. Specific objectives include (i) understand regional drivers of change, (ii) develop regional scenarios, and (iii) learn sub-regional responses to regional scenario futures. Sub-regional responses are of interest here in order to learn plausible adaptive co-management responses to scenario changes.

Our poly-workshop scenario methodology collects information on the drivers of change from across the region, synthesizes regional drivers of change to create four scenarios then elicits feedback on regional scenarios from three villages and description on the processes villages would engage in to reach the scenario futures. We find sub-regional variation in the processes villages engage in order to reach scenario futures from shared baseline conditions. This suggests specialized approaches to policy and decision-making may be more suitable to rural populations than top-down approaches created from the centralized-workshop scenario planning method.

3.3 Background

3.3.1 Scenario planning

Participatory scenario planning involves stakeholders in the creation of visions of the future which are neither accurate predictions nor forecasts but are plausible accounts of the future (MA 2005, Whitfield and Reed 2012). Scenario planning is a helpful tool for exploring different possible futures in order to better prepare for surprises (Bohensky et al., 2006), often examining drivers of regional change over a period of ten to fifty years (IPCC 2013, MA 2005, Peterson et al., 2003, van Vliet et al., 2010). Scenarios can be useful for future land management decisions and have been used historically by many different sectors (i.e. business, military and sciences) (Malinga et al., 2013, Van't Klooster and van Asselt 2006).

3.3.2 Decision-making and scenarios

Scenario planning has been successful in real-world applications for business, democracy, social learning and education (Patel et al., 2007). Application of decisions resulting from the scenario planning process are reviewed in areas of business and policy (Glenn 2006). The arguably most well-known business application of improved decision-making as a result of scenario planning is the case of the Royal Dutch Shell Corporation. Drivers of change external to the corporation were explored in a scenario planning exercise and the management team left the process in better positions than their competitors to handle shocks in oil prices (Glenn 2006). Scenario planning's application in policy can be seen in the Mont Fleur scenarios where the process resulted in an enrichment of negotiation during South Africa's transition to democracy (Peterson et al., 2003, Scholes and Biggs 2004).

In general, the aim of most scenario planning exercises is to promote social learning, collaboration, and adaptive response to shocks or surprises (Enfors et al., 2008, Malinga et al., 2013). Scenario planning literature with a focus on social-ecological systems seldom report decisions made and executed as a result of the scenario planning process. The reason for this may be limited scientific knowledge on the workings and interactions of ecosystems and society. Daily et al. (2009) stress a need for an advanced understanding of linkages between ecosystem services, decision-making processes, policy implementations and the role institutions in order for more robust decisions to be made regarding ecosystem services. However, in a scenario planning exercise conducted by Enfors et al. (2008) they find a shared theme in all future scenarios; Small scale water systems were considered valuable regardless of scenario in the Makanya scenarios. Scenario planning exercises can result in stronger decision-making if similar trends are seen among scenarios or if the process builds consensus among a diverse set of stakeholders.

3.3.3 The dominant scenario-building process: The centralized-workshop

The dominant workshop scenario planning method gathers regional stakeholders who may be leaders in their field (i.e. policy leaders, business managers, scientists, NGOs). Smallholder voices are under-represented in regional decision-making conversations (Scholes and Biggs 2004, Foley et al., 2005, Woods 2012). Rural populations have a greater understanding on the local processes and problems which shape their communities (Patel et al., 2007). Therefore, key narratives may be absent from regional scenario planning exercises because rural stakeholders are not often involved in major political and market decisions (Whitfield and Reed 2012).

Rural areas differ in economy, infrastructure, landscape, culture, demography and other factors compared to urban areas (Ghelfi and Parker 1997). Therefore, drivers of change which affect urban residents are intrinsically different than drivers which affect rural populations. Currit and Easterling (2009) state demographic factors are a notable driver of change—areas different in demography may be influenced by change in different ways. If a majority of stakeholders in a regional scenario planning exercise reside in urban areas, the drivers of change discussed, of which scenarios are founded on, may be biased toward those which affect urban populations.

Diverse land use trajectories in rural areas further enhance the need to study sub-regional local response to regionally shared visions of the future. For example, rural communities may face either intensification or extensification changes of land use as a result of increased urban demand for a food product (Brondízo et al., 2002). There are many drivers behind rural land use decisions and therefore, within-community response can be very diverse. In support, Verburg et al (2010) state, “the same driving factors may lead to a different result at different locations as a consequence of a different context and different location characteristics” (e.g. Brown et al., 2005). While Verburg et al. (2010) call for region-specific studies on the reasons for land use change, we argue for examination of tailored sub-regional response to regional change.

The centralized-workshop scenario planning approach to regional decision-making can be further improved by taking a more bottom-up approach. A poly-workshop approach to scenario planning where workshops are held in rural sub-regions may better include rural livelihood perspectives on current rural conditions, drivers of change, and processes to achieve future scenario states.

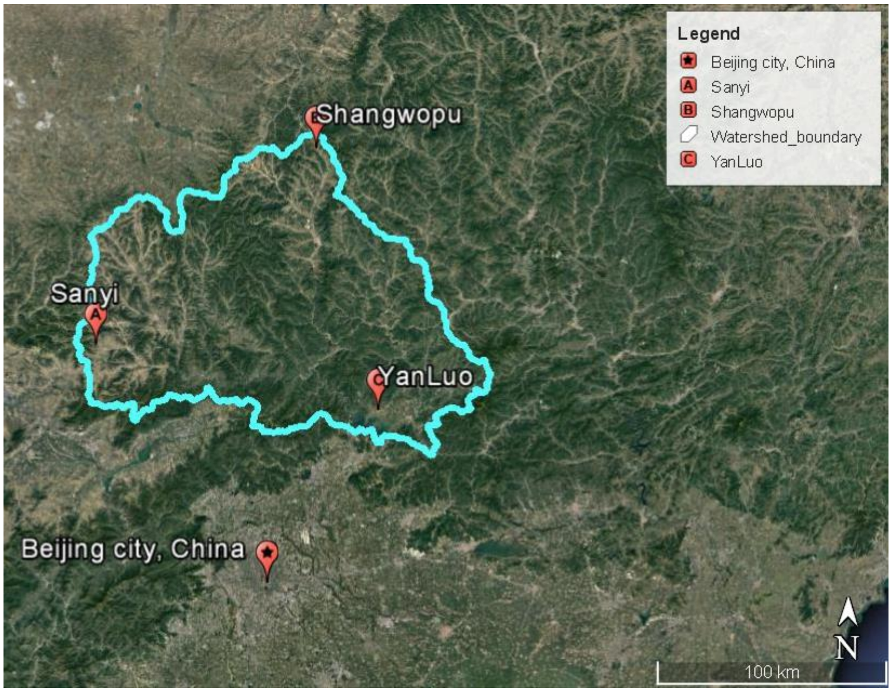
Further, the poly-workshop approach can provide local stakeholders who may not have the financial resources to travel to a central location the opportunity to participate (Patel et al., 2007). Visiting sub-regional locations provides the researchers with added perspective on the land and livelihood conditions of sub-regional locations in the study area.

Visiting locations multiple times allows rural participants the opportunity to work for a majority of the day rather than miss a full day of work in order to participate. In this way, participation in the exercise may be more favorable and participation rates may be higher than holding a single workshop. The addition of new participants in the second workshop may add creativity, depth and historical knowledge to scenario storylines (Patel et al., 2007). The progress made from the first workshop can be built upon and further refined in the second workshop, thus enhancing the participatory experience and strengthening the results of the scenario planning process (Patel et al., 2007).

3.4 Methods and Materials

The Miyun watershed has an area of approximately 15788 km^2 (Ying and Xue-Jie 2012) and is located roughly 100 km north of Beijing (Zheng et al., 2016) (Figure 2). The catchment area has a population of about 878,000 (2011) and about 92% are involved in agricultural practices (Zheng et al., 2016). The watershed is protected under numerous land use policies which aim to improve water quality and quality of the Miyun reservoir (Zheng et al., 2013). The Miyun reservoir provides Beijing with 75% of its total freshwater resources (Kröger et al., 2012) and is Beijing's only source of surface water for domestic use (Zheng et al., 2016).

Figure 2: Google Earth image of Miyun watershed, China and three study villages namely Sanyi (Village A), Shangwupo (Village B) and Yanluo (Village C).



The three study villages selected around the Miyun watershed were Sanyi (Village A), Shangwupo (Village B), and Yanluo (Village C) (Figure 2). The villages are diverse in livelihood profiles and are geographically dispersed. Village A has a diversified livelihood profile which includes farming, transportation, tourism and blue collar work. Village B is dominated in agricultural livelihood activities. Village C is located near the Miyun reservoir and is heavily focused on reservoir protection, eco-tourism, and limited farming activities.

3.4.1 Poly-workshop scenario planning participants

The main participatory group of this study is the local users of ecosystem services from across three villages of the Miyun watershed. Local users include agricultural farmers, economic foresters, those involved in animal husbandry and eco-tourism guides. Their livelihoods are closely linked to the ecosystem and they have specific knowledge of the current conditions and historical events which may have changed the trajectory of local development (Bohensky et al., 2006, Evans et al., 2006, Malinga et al., 2013, Patel et al., 2007, Whitfield and Reed 2012). Other stakeholders involved in the scenario planning process include local government officials (i.e. village leaders), watershed managers, students and members of the community who out migrate for work. Stakeholders were heavily involved in scenario storyline creation (Enfors et al., 2008). The research team visited each village twice in order to complete the poly-workshop scenario planning approach. In the second workshop, approximately 1/3 of the participants had not attended the previous workshop.

3.4.2 Village selection

This thesis aims to examine differences in the processes three villages take to reach four regional scenarios of the Miyun watershed. The specific objectives of the work are to (i) understand regional drivers of change, (ii) develop regional scenarios, and (iii) learn sub-regional responses to regional scenario futures. The creation of four regional future scenarios follows the scenario axes methodology widely used by futurists (Van't Klooster and van Asselt 2006, Daconto and Sherpa 2010, Quinlan 2012).

Household livelihood summary statistics of 15 villages around the Miyun watershed were used to select three villages to conduct the poly-workshop scenario planning exercise. In 2014 and 2015 Zheng and Robinson conducted an extensive household livelihood survey of 15 villages around the Miyun watershed (Peng et al., in review). Approximately 1,700 households were surveyed about livelihood activities and each household's use of the landscape. Summary statistics of the data collected from the survey were used to select villages to represent the diversity of socio-economic conditions, livelihood activities, government aide, environmental, and geographic conditions, but to not represent extremes that exist in the watershed. On average, all villages identify as ethnically Han. To balance research costs and robust data collection, we selected three villages in which to conduct scenario planning workshops.

Three diverse villages were sought in order to gain an understanding of the drivers of change from across the region, find similarities in drivers and synthesize into common scenarios. The villages selected were Sanyi (Village A), Shangwupo (Village B), and Yanluo (Village C).

Yanluo is located in Beijing municipality while Sanyi and Shangwupo are in Hebei province (Table 1).

Table 1: Descriptive statistics of Village A, B and C from 2014, 2015 household survey (Peng et al., in review).

Village	Location	Main livelihood activity	Percent of households	Secondary livelihood activities	Percent of households
Sanyi (Village A)	Hebei Province	Crop farming	54%	Blue collar, transportation	3%, 2%
Shangwupo (Village B)	Hebei Province	Crop farming	68%	Livestock, tourism	2%, 2%
Yanluo (Village C)	Beijing Municipality	Crop farming	45%	Blue collar, commercial	16%, 6%

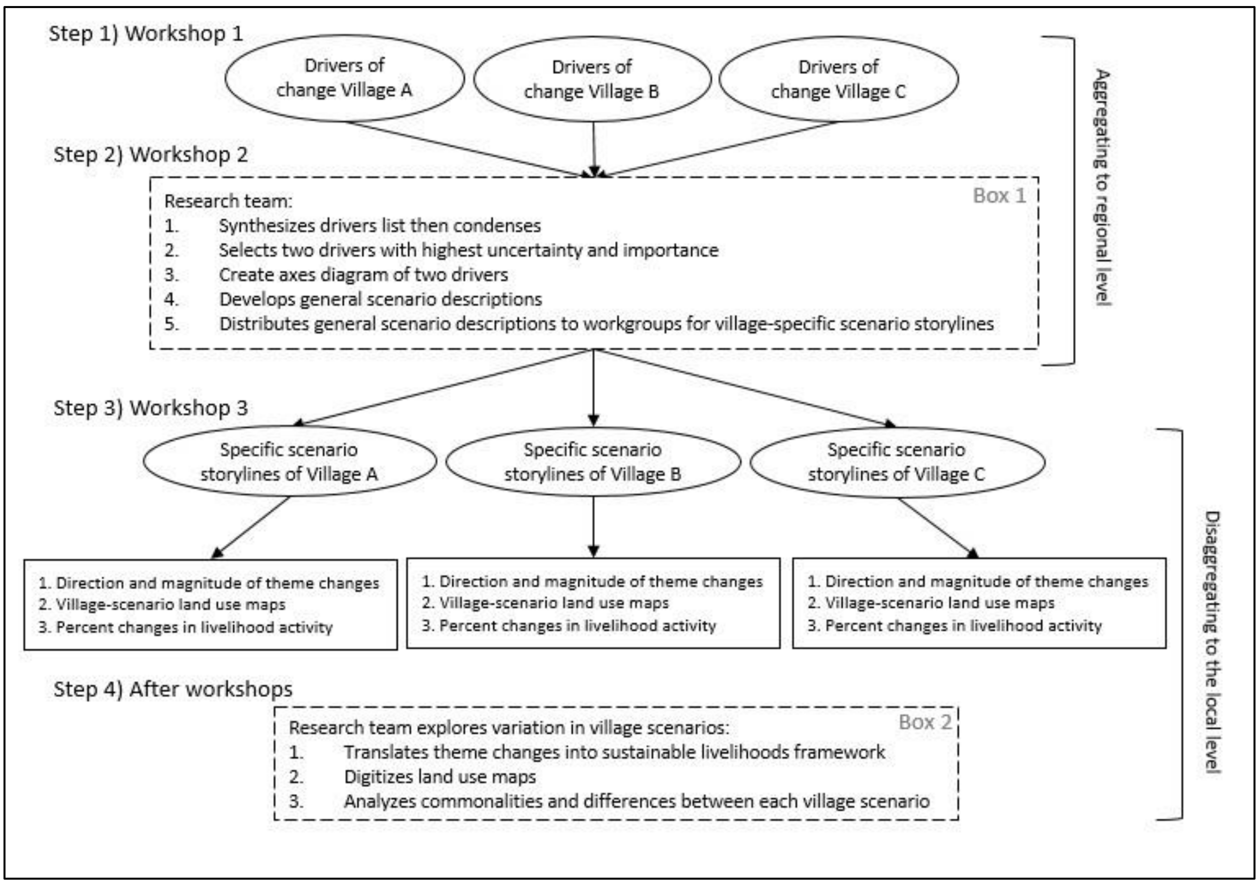
The scenario planning process took place over the course of two days at Village A, B and C with an average duration of one and a half hours each day. Total number of participants present was 42; each site had approximately ten participants per workshop. The workshops were conducted in Mandarin Chinese.

Stakeholder groups present in Village A, B and C of both scenario workshops included, rural residents, local user groups of ecosystem services (Bohensky et al., 2006, Evans et al., 2006, Malinga et al., 2013, Patel et al., 2007, Whitfield and Reed 2012), local government, watershed managers, students and out migrants for work. Village leaders helped recruit stakeholders. Overall, male participants dominated the workshops and the approximate average age range of all participants was between 45-60 years old.

3.4.3 Workshop 1: Assessing regional drivers with each community

The objective of the first workshop was to develop a common understanding of historic drivers of change that affect all villages and the region broadly (Figure 3, step 1). This parallels the approach taken in the centralized-workshop method, but attempts to aggregate information across separate workshops with separate populations. The research team conducted half-day workshops at each village to assess drivers of change from all stakeholders and over all geographic locations. Facilitators began this workshop with an introduction presentation on the scenario planning process and proceeded to create a list of the major driving forces of change. Second, the participants ranked items by highest importance and uncertainty (Quinlan 2012, Van't Klooster and van Asselt 2006), as discussed below.

Figure 3: The poly-workshop scenario planning approach.



Following the presentation, the participants and facilitators engaged in an ice-breaker interview on the livelihood activities of community members. Ice-breaker interviews were conducted in focus groups of 4-5 participants. During the interview, participants provided information on their village (i.e. the types of crops grown, average annual household income, their thoughts on environmental quality and quantity, general likes/dislikes etc.) and it also served as confirmation and validation of the data collected in the earlier household livelihood survey. Qualitative and quantitative data were recorded on item-specific datasheets by the facilitators.

After the interview, focus groups converged to discuss drivers of change. The research team explained that the drivers of change can be either internal or external to their village and can be factors that have shifted development trajectories of their village in the past or factors which underlie recently seen changes (Quinlan 2012). We asked participants to each think of 5-10 major drivers of change at each village (Daconto and Sherpa 2010). Each participant described the drivers they thought important. Approximately 8-12 drivers had common overlap at each location. Each participant was then asked to identify the two drivers they felt were most important and the one driver they felt was most uncertain (Postma and Liebl 2005, Van't Klooster and van Asselt 2006, Quinlan 2012).

A driver of change with high importance was defined as having a high impact on the social, economic or physical conditions of their village (Van't Klooster and van Asselt 2006). When selecting for uncertainty, we asked participants to mark drivers of change about which they were most unsure it would develop in the future (Enfors et al., 2008). After the completion of the first scenario planning workshop at the study sites, the research team synthesized the stakeholder-identified drivers of change across all three villages to create regional scenarios.

3.4.4 Workshop 2: Internally Synthesize regional drivers into regional scenarios

Following the first workshop, the research team engaged in an internal workshop exercise to synthesize the lists of drivers of change collected from all villages (Figure 3, step 2). The research team translated the two highest ranked drivers of change into two axes from which four scenario quadrants were created.

Following creation of the scenario quadrants, the research team developed a narrative of the general conditions present in each quadrant (Figure 3). These general conditions were then distributed to each village during the second workshop to gather each locations' narrative on how each of the conditions present in each scenario would play out in that location into the future.

3.4.5 Workshop 3: Assess local implications of scenarios with each community

From the regional scenarios villages generate village-specific approaches to reach regional future scenarios. The objectives of the second workshop were (i) develop a storyline for each scenario in each village (4 scenarios in 3 villages resulted in 12 distinct storylines), (ii) learn local user groups' thinking on where scenario changes may occur and the type of land use changes, and (iii) understand the possible shifts in future livelihood activities for each scenario.

The second workshop began with a presentation reviewing the tasks completed in the previous workshop and the objectives of the second workshop. For theses workshops, the research team again conducted half-day workshops in each village.

During the second workshop, participants divided into 4 groups of approximately 3-4 people per group, to discuss possible storylines for each scenario. Each workgroup was assigned a scenario quadrant to develop a plausible future storyline. We asked participants to imagine scenario storylines to extend approximately 20 years into the future, and workshop facilitators asked guiding questions to assist storyline creation. After workgroups completed their scenario storylines they presented their storyline to the village participants for confirmation and feedback. Any necessary modifications to storylines were made, and the data presented here reflect the final versions that incorporated group feedback.

We asked workgroups to estimate how future scenarios implied changes in local livelihoods. We categorized our questions into the five "capitals" of the sustainable livelihoods framework, drawing on previous work in the region (Peng et al., in review): natural capital, physical capital, financial capital, human capital and social capital (Scoones 1998, Ellis 2000, Adato and Meinzen-Dick 2002). Natural capital includes responses that relate to changes in air, water, biodiversity and environmental policies; physical capital includes changes in roads, irrigation, electricity, information technology, farm extension policy, and new seeds; financial capital includes income, assets and employment opportunities; human capital includes health, welfare, education, and skill training; and social capital includes changes in inequality, local migration and out migration (Hagan et al., 1996, Schiff 2002). Presenting the same themes to each workgroup enabled comparison of scenario outcomes between villages (Mahmoud et al., 2009).

Each village scenario workgroup gave a response to the direction and magnitude of each theme change. For each storyline in each village, participants indicated the direction and magnitude of change on a Likert scale of 1 to -1, indicating ‘much better’ to ‘much worse’, for each topic included in our “capitals” questionnaire. We took the average of all responses within each capital category (i.e. aggregating an average impact on air, water biodiversity, environmental policies for natural capital) to generate an average likelihood of change (improvement or decline) in that category (Appendix 1a). Specific items within each sustainable livelihood capital category were added and divided by the sum of the number of specific items within each larger category (Appendix 1b). The results are ranked sustainable livelihood capitals for each village scenario. Responses to metrics within each capital category (i.e. air, water biodiversity, environmental policies) were averaged to generate percentage change in that category (i.e. natural capital).

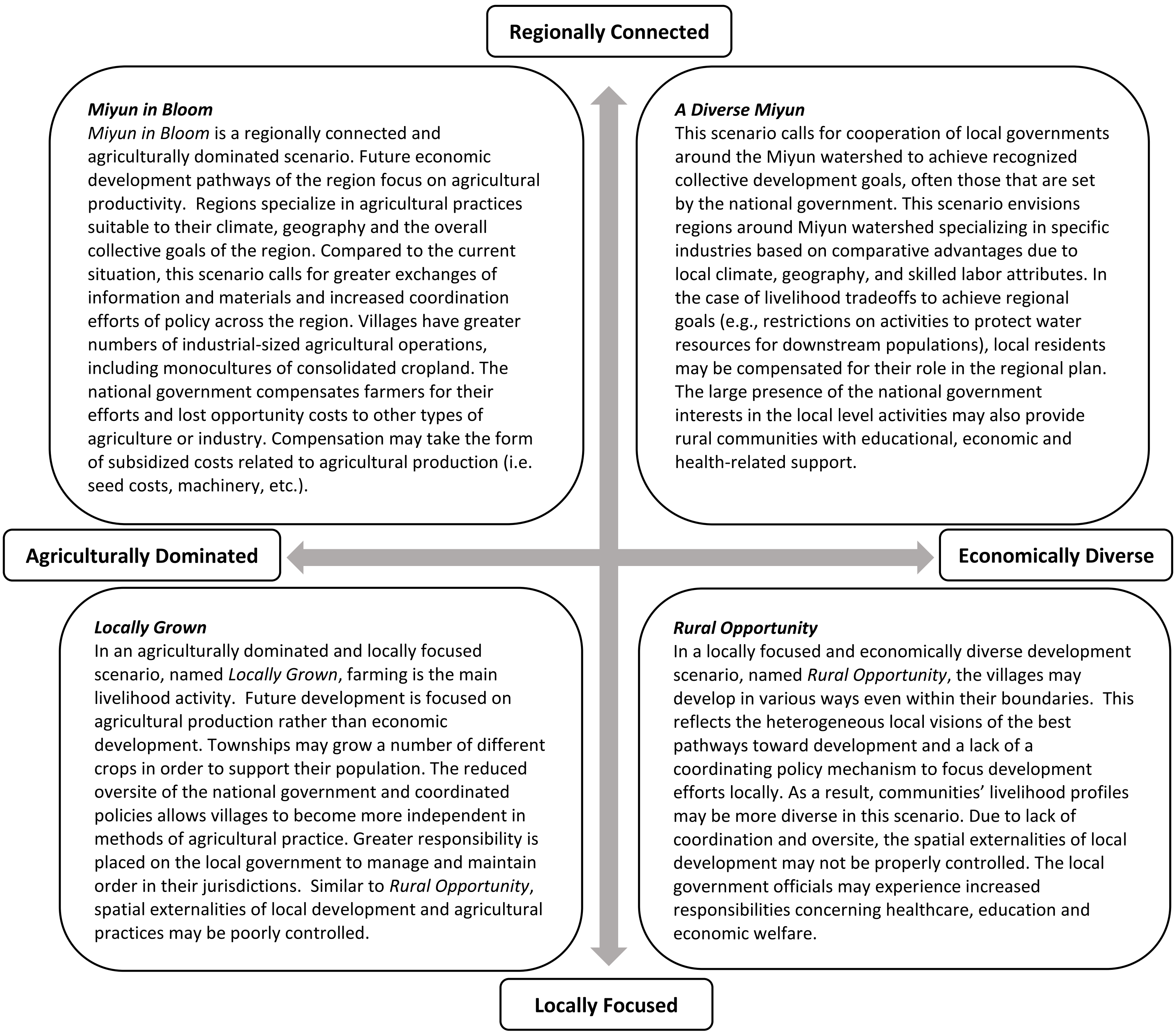
Next, workgroups marked areas of future scenario land use/ land cover change on large areal image maps and described percent change of livelihood activities in each village scenario. Following the second workshop, the research team digitized marked village scenario maps (Appendix 2). Percent change in livelihood activity will be discussed further in Chapter 4.

Final storylines were reviewed by the research team, following standard scenario methods (Carpenter et al., 2015, Mahmoud et al., 2009, Malinga et al., 2013). Exit surveys were distributed at the close of each workshop to provide the research team with feedback which could be incorporated into the next village workshop. Surveys also allow participants to voice their opinions in a more private setting (Daconto and Sherpa 2010, Patel et al., 2007).

3.5 Results

The poly-workshop scenario planning approach involved two visits to three villages around the Miyun watershed where the first visit consisted of an introduction to scenario development and creating ranked lists of drivers of change for each village. The results of the first workshop contributed to the methodology of the second workshop. The research team synthesized drivers of change across all villages and developed scenario axes and quadrant conditions (Figure 4). These regional scenarios that are common to all the villages were presented at the second workshop in Villages A, B and C to create village-specific storylines. Village scenarios include specific processes villages would engage in to reach the futures of each regional scenario.

Figure 4: Scenario axes and general conditions developed by the research team after regional drivers were synthesized.



3.5.1 Regional Scenarios

We found common drivers of change mentioned in all villages and cases where some drivers of change seemed village-specific. The importance rankings of the drivers in each village varied, but commonalities emerged. Table 2 summarizes the aggregate drivers of change that were most important and uncertain over all the villages.

Table 2: A condensed list of the drivers of change according to highest percentage of participant vote on importance and uncertainty.

Rank		Driver
Importance	Uncertainty	
35%	11%	Social policy
28%	0%	Eco-compensation
12%	26%	Private investment
12%	15%	Technology
7%	15%	Public investment
4%	0%	Land consolidation policy
2%	19%	Population
0%	11%	Climate
0%	4%	Local government

Drivers of change that related to policies and governance were interpreted as the degree to which government actions influence local opportunities and constraints within the village. The degree of government influence is portrayed on the north-south axis on a scale from “regionally connected” to “locally focused” (Figure 4). Private and public investment and technology were portrayed as pathways to development of the villages relative to their current agricultural base. This axis ranges from “economically diverse” to “agriculturally dominated” (Figure 4). This creates a quadrant of four scenarios as a combination of the extremes on each axis.

The regional scenarios are *A Diverse Miyun*, *Rural Opportunity*, *Locally Grown* and *Miyun in Bloom* (Figure 4). The combination of economically diverse and regionally connected factors creates the scenario *A Diverse Miyun,* where communication and transportation networks are coordinated across the region in order to advance collective development goals. Economically diverse and locally focused factors create the *Rural Opportunity* scenario where sub-regions are governed by local governments and develop in diverse ways within the boundaries of their village. Agriculturally dominated and locally focused factors result in the *Locally Grown* scenario where villages engage increasingly in agricultural activities and are lead increasingly by the local government. Agriculturally dominated and regionally connected factors result in the *Miyun in Bloom* scenario where the regional government oversees village agricultural production and assists with logistical and financial plights.

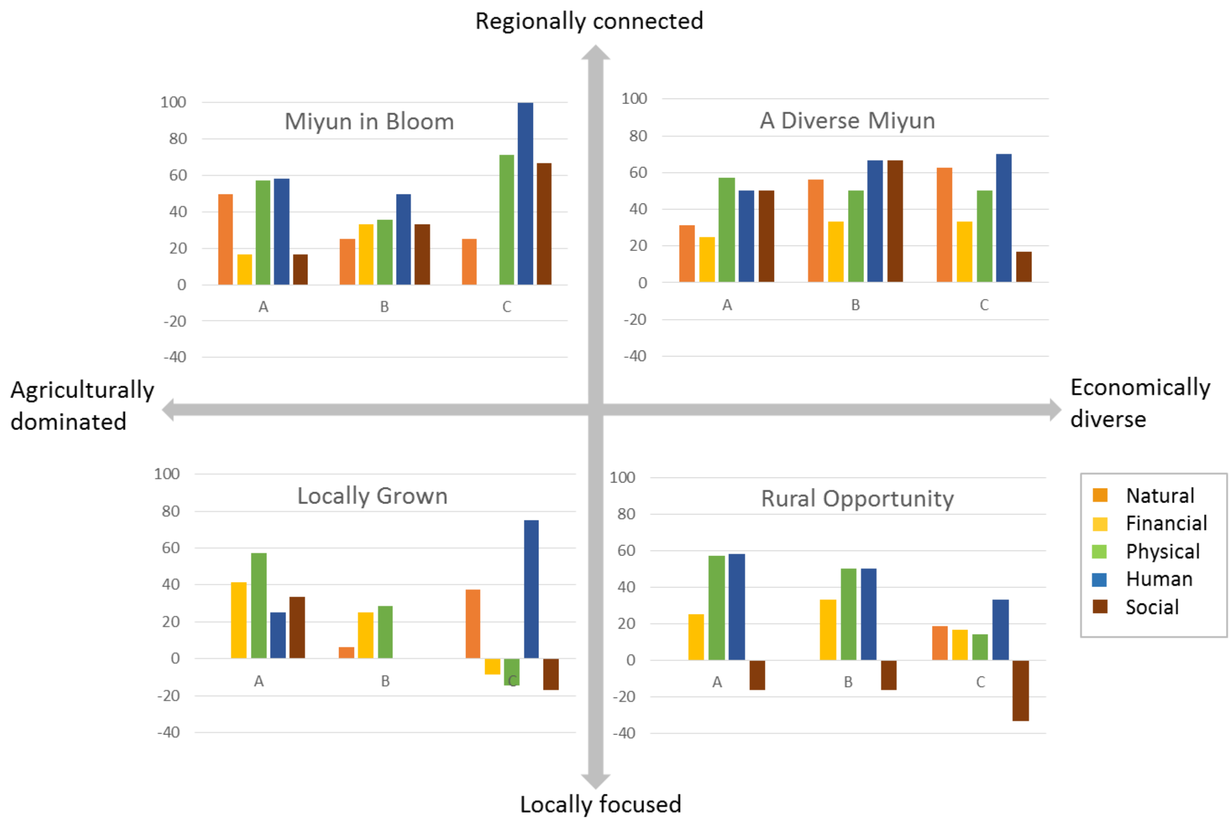
3.5.2 Storyline Similarities

Village-scenario storylines correspond to additional information collected in the second workshop. Sustainable livelihood capital changes (Appendix 1b), land use/land cover changes and percent changes in livelihood activity reflect the storyline narratives of each respective village scenario storyline.

While villages report variation in scale and type of land use/land cover changes in each scenario we do find commonalities (Appendix 2). In *A Diverse Miyun* Village A, B and C report additions of natural and economic forestry. In *Rural Opportunity* all villages indicate the addition of industrial land use/land cover. *Locally Grown* experiences additions of agricultural landscapes such as economic forestry or farmland in all villages. In *Miyun in Bloom* villages do not indicate similar land use/land cover changes but their storyline narratives are similar. All villages indicate the importance of regional connectivity and government assistance in agricultural development of *Miyun in Bloom*.

Scenario percent change in livelihood capital is also similar among villages. Each village gave information on the direction and magnitude of the sustainable livelihood capitals (natural, financial, physical, human and social) (Figure 5). Percent change for each capital was calculated by adding rankings (-1 to 1) of items within each capital and dividing by the number of total items within a capital. Rankings range from positive 100 percent to negative 100 percent. In general, we find higher percentage changes – or more positive responses to sustainable livelihood capitals in *A Diverse Miyun* and *Miyun in Bloom*; suggesting that regionally connected scenarios improve sustainable livelihoods for all villages (Figure 5). In contrast, lower percentage changes in sustainable livelihood capitals are found in locally focused scenarios (*Rural Opportunity* and *Locally Grown*).

Figure 5: Percent changes of ranked specific themes with each of the five sustainable livelihood capitals. Items within each livelihood capital category were ranked on Likert scale of becoming "much worse" to "much better" then translated to a numeric scale of -1 to 1. Range of response to theme changes ranges from -100% to 100%.



3.5.3 Village-specific processes to scenario futures

While villages do respond similarly to scenarios in some ways, they also react in very distinct, locally specific ways as well, as revealed in their village-specific scenario storylines.

A Diverse Miyun calls for regional connectivity in communication, economic and social development to achieve regional goals. In *A Diverse Miyun* all villages mention tourism in their scenario storyline but the types of tourism differ between each village. Village A engages in tourism related to winter activities as a result of the 2020 Beijing bid for the Winter Olympics. Village B develops an eco-tourism sector focused on the beauty of its East Mountains showcasing wildflowers and biodiversity. Village C engages in restaurant tourism where local villagers open bed and breakfast locations and offer sight-seeing tours.

The *Rural Opportunity* scenario calls for economic diversity in development at a local scale (area including and surrounding the village). In *Rural Opportunity* all villages indicate additions in local industrial activity but types of industrial activity differ between villages. Village A engages in fruit tree product processing. Village B's local government helps to consolidate farmland for easier cultivation and processing of agricultural products. Village C indicates the addition of clothing and packaging companies less than 1 km from their village.

In *Locally Grown*, development is dominated by agricultural production and most government decisions are made at the township or provincial level. All villages indicate advancements in the agricultural sector in *Locally Grown* but the types of advancements differ between villages. Village A utilizes information technology, skill training and increases fertilizer inputs to advance their agricultural economy. Village B constructs a reservoir for purposes of cropland irrigation. Village C experiences their largest area increase of economic forest, increased fruit tree production and employment in economic forest-related opportunities.

Miyun in Bloom is a scenario where development is focused on agricultural production and the watershed is governed as an interconnected region. In *Miyun in Bloom* all villages indicate government financial support for different types of development. Village A engages in reforestation of natural forest and receives government funding for their efforts. The government reduces income inequality in Village B by reducing taxes on lower income people. In Village C it is apparent a future in agricultural production is not feasible because of close proximity to the Miyun reservoir so the government relocates Village C to a nearby city and villagers are compensated for moving.

3.5.4 Exit survey

Three main questions were asked in the exit survey to understand participant's response to the scenario planning methodology. When asked if the workshop was useful in expressing his or her point-of-view out of the responses yes, relatively or no, 80 percent of respondents stated 'yes' while 20 percent stated 'relatively'. A majority of respondents (86%) stated they were satisfied with their contribution to the group discussion; while 14 percent stated they were relatively satisfied. Finally, when asked if they thought the workshop clearly identified issues in their area 84 percent responded 'yes' while 16 percent responded 'relatively'. The space for additional comments was left blank except for one instance where a participant suggested "[the research team] could do some real helpful things for us".

3.6 Discussion

This scenario planning methodology was designed to highlight a range of local stakeholder response to a similar set of issues. The poly-workshop scenario planning method exhibited here marginally increases time and resources devoted to the scenario process, but we argue that we gain a better understanding of potential sub-regional development patterns, and how populations vary in ideas, values, livelihoods and socioeconomic conditions.

Centralized-workshop scenario planning and decision-making may be most useful at large spatial and temporal scales because of regional leaders' ability to coordinate policies across scales and ensure continuous operation of the decision processes. Large-scale policy decisions may be effective for climate change adaptation measures biodiversity conservation, food security, and freshwater protection (Foley et al., 2005, Urwin and Jordan 2008), but diversity in local response to these policy decisions must be considered.

Urwin and Jordan (2008) suggest both a top-down and bottom-up approach ought to be incorporated in regional decision-making processes because the top-down approaches may fail to incorporate cross-scale implications and smallholder points-of-view. They further state top-down approaches alone may fail to grasp complicated cross-scale and cross sectoral interplays. Foley et al. (2005 p. 572) state "there is an increasing need for decision-making and policy actions across multiple geographic scales and multiple ecological dimensions". Poly-workshop scenario planning can be used to shape large-scale decisions to local geographies and incorporate local social-ecological niches into specific plans of action.

There may be strategies beneficial to both rural populations and regional decision-makers. The adaptive co-management literature reflects this thinking. Armitage et al. (2009) define adaptive co-management as a ‘flexible system of resource management tailored to specific places and situations, supported by and working in conjunction with various organizations at different scales’. Place has been defined as areas where individuals or groups associate meanings, beliefs, symbols or feelings (Williams and Stewart 1998). The notions of place, region and scale are interconnected (Paasi 2004) and therefore, we argue place must be defined specific to the research question and outcomes a party is interested in.

If a decision-makers’ goal is to create policy that results in a specific outcome over a whole region, better understanding the diversity in local responses is crucial for meeting policy goals (Zheng et al., 2013). Our sample villages exhibited diverse responses to four common scenarios created from shared regional drivers of change. This dramatic diversity in response suggests the poly-workshop approach should be an active part of the practitioner’s toolbox to incorporate regionally-representative views in stakeholder-informed planning processes into the future.

After exploring sub-regional heterogeneity, a policy focus on the shared values may be more beneficial than applying all facets of a policy where sub-regional diversity in response is found. The decision to apply sub-regionally specialized policies may result when there is contrast in response to a similar set of issues. The poly-workshop method can help develop localized strategies to accomplish goals of a proposed regional policy initiative.

3.7 Conclusion

The scenario storylines of Sanyi (Village A), Shangwupo (Village B) and Yanluo (Village C) highlight diversity in response to a common set of issues, reveal areas of contrast in sub-regional economic development and the roles of regional or local government and major similarities across scenarios and villages.

Future large-scale policy efforts must focus on the shared values of sub-regions in order to be more effective. Blanket policies applied to a region do not account for sub-regional variation in response to certain issues. If sub-regional diversity in response to a common scenario set of issues arises specialized policies must be considered.

Chapter 4. Resilient futures: using scenario analysis to identify winners and losers from ecosystem service change [2]

4.1 Abstract

Rural populations are dependent on harvesting various types of natural resources for their livelihoods. The extent to which households are reliant on ecosystem services is difficult to measure because rural households are diversified and utilize both direct and indirect ecosystem services in their daily lives. It is also unknown to what extent ecosystem service dependency varies across time, and main household livelihood activity. We build on baseline livelihood ecosystem service dependency measures from a household livelihood survey and use participatory scenario planning to generate future ecosystem service dependency measures. Scenario planning is used here as a method to explore plausible future states and the future proportions of village populations involved in various livelihood activities associated with each scenario. We conducted scenario planning exercises in three separate villages of the 15 surveyed within the Miyun watershed, China. The scenario planning exercises resulted in four plausible future states of the Miyun watershed. By comparing baseline ecosystem service dependency measures for village livelihood activities to the future scenario population proportions of livelihood activities we find future livelihood type ecosystem service dependency measures for plausible future states of three villages in the Miyun watershed. In the scenarios where development is focused on agricultural production ecosystem service dependency is expected to increase. In the economically diversified scenarios dependency on ecosystem services is expected to decrease. The results reveal regionally connected scenarios behave as we may expect in terms of changes in future ecosystem service dependency whereas locally focused scenarios behave unexpectedly. Future ecosystem service dependency measures may be useful for examining possible shifts in the direct use of natural resources.

4.2 Introduction

Rural populations are often highly reliant on ecosystem services for their livelihoods; livelihood strategies are diverse, but may be dependent on ecosystem services for food, fuel, health income and employment (Ellis 2000, MA 2005, Vedeld et al., 2007, Daily et al., 2009, Tieguhong and

[2] This chapter is intended to be submitted as manuscript for a scientific journal.

Nkamgnia 2012). Measuring the extent to which rural populations are dependent on ecosystem services is of interest in order to better understand rural livelihoods, adaptation strategies, inequality, and the intricate interactions between people and natural resource use (Angelsen et al., 2014).

Approaches to measure ecosystem service dependency vary within the literature. This may be due to a lack of understanding on the extent of the relationship various households have to the ecosystem services they collect. Further, ecosystem service dependency can vary across time, space and population group (Yang et al., 2013). Ecosystem service dependency studies typically focus on a single type of ecosystem service (i.e. forest products) and that service's contribution to household income (Vedeld et al., 2007, Angelsen et al., 2014). However, the foundations built by forest income dependency studies help in the calculation of household dependence on multiple ecosystem services. This study builds on an in-depth household livelihood survey conducted in the Miyun watershed from which current livelihood ecosystem service dependency measures were calculated.

Understanding future reliance on local ecosystem services is crucial to supporting rural livelihoods and can help guide spatial land use planning. Participatory-developed scenarios are used to explore plausible future states of regional social-ecological systems, and have the ability to incorporate uncertainty and important regional drivers of change (Carpenter et al., 2006, Malinga et al., 2013). In regional scenario planning exercises stakeholders from key sectors with varying degrees of degrees of decision-making power are invited to participate (Patel et al., 2007). Often, stakeholders have to travel far distances to reach the central location where the exercise is held. In some cases, key stakeholders (i.e. small-scale farmers and local ecosystem service user groups) are not represented during scenario planning workshops because of lengthy travel distances (Patel et al., 2007).

Despite the interest and focus on rural reliance on ecosystem services, this important scientific focus requires more research on the assessment of local-level vulnerability to future changes in ecosystem services. This research aims to lay the foundations for future ecosystem service dependency measurements of rural populations. The overall objective of the research in this chapter is to assess the extent of this vulnerability for discrete populations over a 20-year time horizon. Specific objectives include (i) understand baseline livelihood ecosystem service dependencies from a previously conducted household survey, (ii) connect baseline measures with livelihood type changes from the village scenario planning exercises and (iii) estimate plausible future changes in the study population's livelihood activities and the corresponding change in their dependence on ecosystem services. We estimate plausible future changes in livelihood dependency on ecosystem services by connecting the learned scenario changes in livelihood activities (see Chapter 3) to baseline ecosystem service dependency measures from a unique household survey.

After the creation of the scenarios, hypotheses were developed around ecosystem service dependency changes in each scenario. We expect ecosystem service dependency will be higher than baseline current conditions in the agriculturally dominated scenarios (*Miyun in Bloom* and *Locally Grown*) because of the increased production and activities surrounding agriculture; and lower than baseline current conditions in the economically diverse scenarios (*A Diverse Miyun* and *Rural Opportunity*) because of increased service sector growth and reduced focus on agriculture.

We find ecosystem service dependency increases in the regionally connected and agriculturally dominated scenario and decreases in the regionally connected and economically diverse scenario. In the scenarios where more responsibility is given to the local village governments future changes in ecosystem service dependency do not follow expectations.

4.3 Background

This study draws on two main bodies of literature, namely, ecosystem service dependency and scenario planning. We first review the ecosystem service dependency literature, its definitions, methods of measurement, and discuss the gaps found and how the major findings influence our study's contribution to ecosystem service dependency field. Later, we discuss how scenario planning as a systematic method is helpful to explore future shifts in livelihood ecosystem service dependency measures.

Building on the reviewed literature, we use an approach to measure ecosystem service dependency that accounts for diversity in household livelihood strategies. Scenario planning literature offers insights on participatory techniques to explore plausible future states and provides a sound intermediate methodological step from which to develop future ecosystem service dependency measures.

4.3.1 Ecosystem service dependence

The concept of ecosystem service dependency is not yet well-developed in scientific literature. This section examines ecosystem services literature and develops our working concept of ecosystem service dependency. Ecosystem services are defined as the benefits humans receive from nature (MA 2005, Fisher et al., 2009). The benefits people receive from nature are many. Ecosystem services are divided into four categories: supporting, regulating, provisioning and cultural (MA 2005). Provisioning services which benefit humans, and rural populations in particular, include non-timber forest products (NTFPs) (i.e. mushrooms, medicinal plants etc.) fuelwood, wild fish, freshwater supply in the form of precipitation, and soil erosion control. Dependency measures are not typically calculated for indirect benefits to people because they are difficult to measure.

Forest income dependency literature provides foundational information towards the development of an ecosystem service dependency concept. Forests are one type of ecosystem and populations who live near forests are often reliant on its products for fuelwood, medicine, NTFPs, construction material, etc. (Zenteno et al., 2012). However, because forest income dependency studies do not include direct benefits from non-wild or cultivated resources (i.e. forest plantations, agriculture, fish farms), the forest income dependency measures do not truly encompass the concept of ecosystem service dependency. Ecosystem service dependency by definition would include all ecosystem services including those from cultivated resources such as fruit tree plantations, agriculture and benefits from keeping livestock.

A household's proportion of income attributable to forest income is interpreted as proportion income dependence on forest resources. To calculate forest income dependence, total household income is first calculated. It is common to include household products both consumed and sold at market price in gross income (Mamo et al., 2007, Tieguhong and Nkamgnia 2012). Similarly, Angelsen et al. (2014) define income as the gross value of products to produce cash income and those extracted for subsistence at market price. In some cases labor is included as valued added to total profit (Sjaastad et al., 2005, Mamo et al., 2007, Angelsen et al., 2014). Expenditures, fines and damages by wildlife were deducted from gross income (Sjaastad et al., 2005, Mamo et al., 2007, Tieguhong and Nkamgnia 2012). Next, total household income is compared to total forest income (TFI) (Vedeld et al., 2007). The relative share of forest income in total income is considered resource dependency (Vedeld et al., 2007). The effect of environmental income on total income is examined by dividing the sample population into total income quartiles (Narain et al., 2008) or quintiles (Sjaastad et al., 2005, Mamo et al., 2007, Vedeld et al., 2007, Tieguhong and Nkamgnia 2012, Angelsen et al., 2014) in order search for relationships between TFI and socio-economic group.

Ecosystem service dependency measures are important to consider over time and space. Forest income dependence measurements attempt to account for seasonal employment. Narain et al. (2008) propose a "long-term" resource income dependency measure where they collect household income data three times over the course of a year to estimate household permanent income for a year and thereby, annual household dependence on forest resources. Spatial considerations of ecosystem service dependence include participatory mapping exercises and modelling calculations. Mapping ecosystem service dependence on the landscape is commonly interpreted as ecosystem service landscape demand (de Groot et al., 2010, Burkhard et al., 2012). Ecosystem service demand mapping can be performed quantitatively by determining the benefits people receive from natural land use/ land cover (soil quality, vegetation) and climate among other factors (Burkhard et al., 2012). Participatory mapping of ecosystem service demand is another method to spatially determine ecosystem service dependency measures. Participatory mapping collects information on the locations of where local user groups use cultural ecosystem services (Plieninger et al., 2013), and other natural resource products (Peng et al., in review).

Rural household livelihood diversification is also important to consider while studying ecosystem service dependency measures because most rural households are dependent on more than one natural resource for their livelihoods (Ellis 2000, MA 2005, Vedeld et al., 2007, Tieguhong and Nkamgnia 2012). Vedeld et al. (2007) and Zenteno et al. (2012) use a diversification index to explore the relationship between multiple household income sources and total forest income. Vedeld et al. (2007) find as diversification increases, total forest income also increases but only up to the point where forest income would equal income from other off-farm activities. We recognize rural households often have diversified livelihood strategies but classify households by the livelihood activity for which they spend more than 30 percent of their time.

Using the foundations laid by forest income dependency literature, current ecosystem service dependency measurements of households' dependent on multiple ecosystem services can be calculated (Robinson in preparation). From a previously collected household livelihood survey, Robinson determines ecosystem service dependency measures by main household livelihood activity type rather than income level. Here, we use these as current ecosystem service dependency measures in combination with participatory scenario planning exercises to find plausible future changes in ecosystem service dependency measures of three study villages in the Miyun watershed, China.

4.3.2 Scenario planning

Uncertain and complex futures of social-ecological interactions have been explored using the participatory scenario planning process (Van't Klooster and van Asselt 2006, Enfors et al., 2008, Daconto and Sherpa 2010). Scenarios are narratives of plausible accounts of the future developed by regional stakeholders who collaborate on important and uncertain drivers of change (Enfors et al., 2008). Stakeholders may include scientific experts, local or regional business people, community leaders, resource managers, and rural and urban residents (Peterson et al., 2003, Evans et al., 2006, Carpenter et al., 2015). Local user groups of ecosystem services may have difficulty attending regional stakeholder workshops locations due to lengthy distances needed to travel (Patel et al., 2007). Rural stakeholders are often under-represented in regional decision-making processes (Scholes and Biggs 2004, Foley et al., 2005, Woods 2012). Under-representation of rural populations can be problematic during regional scenario planning exercises because drivers of change which affect urban residents are intrinsically different than drivers which affect rural populations. Compared to urban areas, rural areas differ in economy, infrastructure, landscape, culture, demography and many other factors (Ghelfi and Parker 1997).

Future impacts of drivers of change thought to be important or uncertain are discussed during a scenario planning exercise (Peterson et al., 2003, MA 2005, Enfors et al., 2008). Drivers of change may include certain policies, social relationships, population, technology, economy, environment and their interactions are considered over time and space (Quinlan 2012, Carpenter et al., 2015).

Increasingly scenario planning is utilized to explore future complex interactions of social-ecological systems in order to better prepare for surprises and promote social learning (Patel et al., 2007, van Vliet et al., 2010). Social-ecological systems typically experience trade-offs as a result of landscape conversion or ecosystem service change. Human influence on land use has been amply documented and new studies are being conducted (IPCC, UNEP). Land use changes directly impact the provisioning services of ecosystem services (Metzger et al., 2006). Scenario planning is a method used to explore future scenario changes in land use, ecosystem services, and development (Metzger et al., 2006, Carpenter et al., 2015).

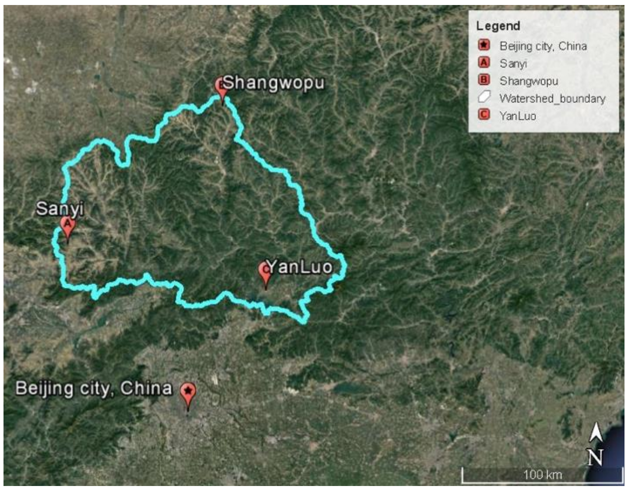
4.3.3 Connecting scenario planning and ecosystem service dependency

We use scenario planning here to inform on future livelihood ecosystem service dependency measures. Scenario planning methodology is a useful tool to explore future changes livelihood ecosystem service dependency measures because of the method’s systematic approach to examining future uncertainty and participatory involvement of local user groups. Scenario planning can be performed with regional or community level stakeholders who are interested in preparing for future surprises in development, policy, land use, or livelihood activities (Peterson et al., 2003, Carpenter et al., 2006, German et al., 2009, van Vliet et al., 2010). Here, participatory scenario planning is used to explore future changes in livelihood activity and the implied future changes in the populations’ ecosystem service dependence. Exploring future ecosystem dependency measures in the Miyun watershed context is interesting because of the recent policy, ecological and landscape changes experienced by the region.

4.3.4 Study site

The study was conducted in three villages of the Miyun watershed, China about 100 km north of Beijing City (Figure 6). The Miyun watershed is considered an important area for freshwater provisioning (Peisert and Sternfeld 2005, Regele 2008). The Miyun reservoir serves the population of Beijing (approximately 20 million) and is responsible for the supply of about 75% of Beijing's freshwater resources (Kröger et al., 2012, Zheng et al., 2013). The Miyun watershed is approximately 15788 km2 (Ying and Xue-Jie 2012) and has a population of about 878,000 (2011) and approximately 92% are involved in agricultural practices (Zheng et al., 2016).

Figure 6: Google Earth image of three study villages in the Miyun Watershed, China. (Adapted from Figure 2 in Chapter 1).



The Miyun reservoir, like many other reservoirs, has a history of upstream pollution (Peisert and Sternfeld 2005). The upper catchment of the Miyun watershed is heavily involved in agricultural activities, mining and fish farming (Peisert and Sternfeld 2005). The headwaters of the Miyun reservoir transport wastewater, and solid waste residues into the reservoir (Peisert and Sternfeld 2005). Increased fertilizer concentrations on farmland and soil erosion and improper household, industrial and commercial wastewater disposal threaten the water quality of the Miyun reservoir (Kröger et al., 2012).

Policies have been developed and implemented in order to protect the water quality and quantity of the Miyun watershed (Zheng et al., 2013). In 2001 the Paddy land to dry land program was initiated in order to mitigate spatial externalities to the Miyun reservoir (Zheng et al., 2013). These policies have converted paddy lands to corn or potato fields, thus limiting nutrient pollution and increase water yield (Zheng et al., 2013). Given this historical context, the future of social-ecological systems in the region can be considered uncertain.

We use scenario planning to explore future states of three villages in the Miyun watershed. Village A, B and C are diverse in geography (Figure 6), climate, socio-economic conditions, landscape, governance and household livelihood activities (Table 3).

Table 3: Descriptive statistics of Village A, B and C from 2014, 2015 household survey (Peng et al., in review) (Adopted from Chapter 3).

Village	Location	Main livelihood activity	Percent of households	Secondary livelihood activities	Percent of households
Sanyi (Village A)	Hebei Province	Crop farming	54%	Blue collar, transportation	3%, 2%
Shangwupo (Village B)	Hebei Province	Crop farming	68%	Livestock, tourism	2%, 2%
Yanluo (Village C)	Beijing Municipality	Crop farming	45%	Blue collar, commercial	16%, 6%

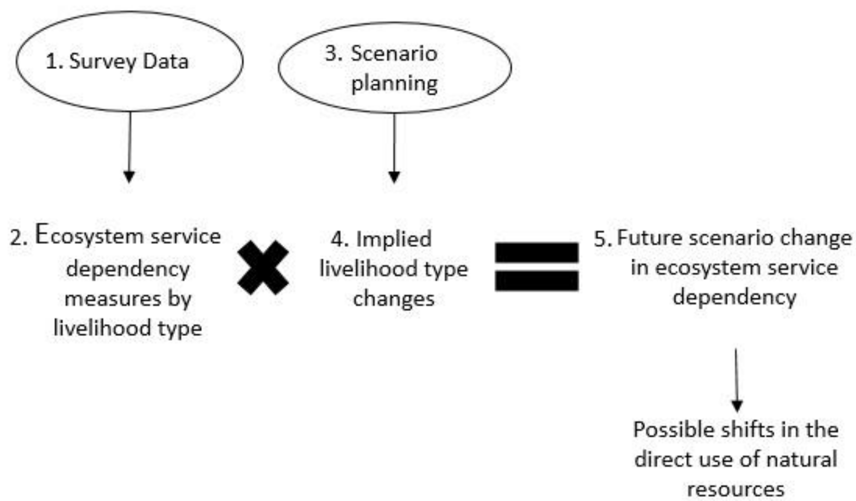
4.4 Methods and Materials

Here, we build upon a household livelihood survey conducted in the Miyun watershed. We compare the current livelihood ecosystem service dependency to participatory scenario planning information on percent changes in livelihood activities.

4.4.1 Household livelihood survey

This study builds on a household survey conducted by McGill University and the Chinese Academy of Sciences in the summers of 2014 and 2015 in the Miyun watershed (Figure 7, step 1). The survey was administered with approximately 1500 households in 15 villages, gathering information on current household livelihood activities (e.g., derived income and time-budgets), expenditures on fertilizer, pesticides, gifts, amount of fuel wood, land use types (i.e. mu (1 mu = 6 acres) of economic forest, natural forest, agricultural etc.), subsidies, assets, and demographic characteristics. Importantly, the survey gathered information on the various ways households use local environmental resources to support their livelihoods activities.

Figure 7: Future ecosystem service dependency framework.



4.4.2 Calculating ecosystem service dependency

From the household survey, we calculate the percent of a household livelihoods that come from ecosystem services. Households may be dependent on (or benefit from) more than one ecosystem service as rural households are often diversified in their livelihood strategies (Ellis 2000, MA 2005, Vedeld et al., 2007, Tieguhong and Nkamgnia 2012). Robinson et al (in prep) describes the methodology for calculating ecosystem service dependency in greater detail but, briefly, we use time budgets and valuation techniques to develop an account of a household's total livelihood activity. We examine household dependence on ecosystem services provided by agriculture, forest and orchard landscapes and livestock resources. Each household may draw from any one of these sources. For agriculture, for example, a household's dependence is calculated by multiplying the amount of a product (for subsistence or sale) by its market value then subtracting by the value of the (non-ecosystem service related) inputs that help produce that agricultural product (i.e. fertilizer, pesticide, herbicide, labor etc.). The result is the ecosystem service net benefit or value attributable to nature of a household. We then divide the net benefits of specific ecosystem services (i.e. agriculture, orchard, natural forest and livestock) by a household's total "livelihood value", which includes both income from all activities plus the potential value of goods produced for subsistence. By dividing the ecosystem service value by the total livelihood value we obtain the percent of a household's livelihoods that are dependent on ecosystem services. Similarly, we estimate the value of ecosystem service to other sources of livelihood, and divide them by the households' total livelihood value to estimate ecosystem service dependence for each livelihood sub-category (Figure 7, step 2). Household values attributable to nature change depending on the types of activities a household is engaged in.

4.4.3 Livelihood type classification

Next, we summarize livelihood type ecosystem service dependencies into an average dependence on four types of resources: agriculture, forest, orchard and livestock. We do this to examine the change in the use of different types of resources in each village scenario. We defined a household as a particular livelihood "type" if the reported number of months engaged in the activity was greater than 30% of the total amount of time engaged in all various household activities. A majority (65%) of households were classified as one type. If two or more activities had more than 30% of the household's time, the household was classified as having two or more types and excluded from baseline ecosystem service dependency calculation. Households with four or more activities were determined by examining if all activities had less than 30%. Diverse households were also excluded from baseline ecosystem service dependency calculation. Categorizing by livelihood type allows for examination of potential winner and loser groups with regards to scenario changes in ecosystem service dependencies. We contribute to the ecosystem service dependency literature by mapping plausible changes in livelihood types and thus changes in ecosystem service dependencies. Ecosystem service dependency measures are reported here by livelihood type rather than by socio-economic status in order to examine variation of ecosystem service dependencies by livelihood type and for practicality, to connect the survey data to future proportion changes in livelihood types from the scenario planning exercises.

Average specific ecosystem service dependency values were calculated for several livelihood types in the survey dataset, we refer to these values as the baseline ecosystem service dependency values for the region. Baseline dependency measures were determined for single household types: farmer, herder, tourism, commercial, transportation, service, manufacturing, unemployed, retired, student, teacher, and government. The average dependencies on agriculture, orchard, forest, and livestock were determined for each livelihood type from the survey dataset. Average ecosystem service dependency values of the survey dataset provide dependency values for livelihood types across the region.

Next, we multiply the average baseline dependencies for each livelihood type and the change in livelihood type populations from the scenario exercises to get the change in dependency for each livelihood type. Future scenario changes in livelihood types, as envisioned by villages, reflect the future change in livelihood type ecosystem service dependency from our regionally-averaged dependencies. This method examines plausible future changes in livelihood type ecosystem service dependencies.

4.4.4 Scenario planning village selection

Three villages diverse in livelihood activity, geography, socioeconomic conditions, and land use were selected for the poly-workshop scenario planning approach. Summary statistics from the survey informed the selection of villages. For all surveyed villages we examined main livelihood activities, socioeconomic characteristics, types of crops grown, and land use (Table 1). The data were also used to understand baseline village conditions for scenario planning exercises.

4.4.5 Poly-workshop scenario planning

Using a poly-workshop scenario planning approach, we visited each village twice to complete the scenario planning process (Figure 8, step 3). The poly-workshop scenario planning approach is a targeted method to involve local user groups of ecosystem services in the scenario planning exercise. The exercise is carried out by visiting sub-regional locations of the study region in order to solicit rural population participation. The workshops were held over a period of two weeks. We visited each village twice. Each workshop was 2 hours long. The objective of the first workshop in the series was to generate a ranked list of drivers of change from the participants. In the first visit, we presented each village with an introductory presentation on the scenario planning process. Next, we facilitated discussion on village drivers of change.

After identification of village drivers of change, participants were asked to vote on the two drivers they felt were most important and the one driver they were most uncertain about in the future (Postma and Liebl 2005, Van't Klooster and van Asselt 2006, Quinlan 2012). We asked participants to consider a driver of change important if it has caused significant impact on social, economic or physical conditions of their village in the past (Van't Klooster and van Asselt 2006). An uncertain driver of change was voted on if participants were unsure about the direction and magnitude of future change (Enfors et al., 2008, Evans et al., 2006). Each village identified approximately 8-12 drivers of change.

The lists of drivers of change from three villages around the Miyun watershed were aggregated and analyzed to determine the two most important and uncertain drivers of change over the whole region. The two most important and uncertain regional drivers of change derived from the village lists were governance level and economic development. Final drivers were placed on two axes to create the scenario axes diagram (Van't Klooster and van Asselt 2006, Daconto and Sherpa 2010). After placing each driver of change on the x and y axis, the research team determines interesting and plausible trajectories of each driver to create contrasting futures of a singular driver of change. This is completed for both drivers of change and the result is four quadrants of plausible and contrasting future scenarios.

In our case, governance level is placed on the y-axis and ranges from locally-focused government to a regionally connected government. Development is placed on the x-axis and ranges from agriculturally dominated to economically diverse Next, the research team developed a narrative of the base scenario conditions that defined each quadrant.

In the second visit to Village A, B and C feedback was solicited on the general scenario descriptions and village participants created unique storylines, specific to how they envisioned each of the four scenario conditions would manifest themselves in their village. The storylines generated from the second workshop include possible land use changes, descriptions on population changes, changes in the environment, business, energy, and policies. Participants in each village were divided into four workgroups of about 3-4 participants. Each workgroup developed a scenario storyline specific to their village. The participatory scenario planning approach involved additional material not discussed in detail here[3].

The participatory process accumulated information from our stakeholders in a systematic way to understand the specific village-level impact of regional scenarios. In the final step we asked workgroups to estimate how they thought livelihood activities within their village would change in each of the four storylines they developed (Figure 7, step 4). These were reported as a percent change in the proportion of the population engaged in that activity type. We used the survey dataset estimate the current percentages of each livelihood activity with Village A, B and C. We draw on these percent changes in village livelihood activities to determine future ecosystem service dependency.

4.4.6 Calculating future ecosystem service dependency

This work builds on current ecosystem service dependency measures from the household livelihood survey. According to our definition of ecosystem service dependency, the measures include multiple sources of ecosystem services used by each household. Ecosystem service dependency measures are categorized by livelihood activity to compare to plausible future scenario percentage changes in the proportion of a village population's main livelihood activity. Future changes in ecosystem service dependency were calculated by multiplying baseline ecosystem service dependency by the change in the proportion of the village population involved in these activities in a given scenario (Figure 7, step 5). This results in future ecosystem service dependency measures for the respective proportion of population involved in each livelihood activity of the village scenarios.

4.5 Results

Baseline ecosystem service dependency measures were calculated from the survey data to infer future change in scenario specific ecosystem service dependency measures for scenario proportion changes in livelihood types across villages. Below, we report (i) baseline livelihood

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[3] For more information, see the previous chapter.

ecosystem service dependencies, (ii) outcomes from the village scenario planning exercises and (iii) estimated future changes in livelihoods and resultant ecosystem service dependencies.

4.5.1 Baseline ecosystem service dependency

Ecosystem service dependence for a specific livelihood type is the average value attributable to nature divided by the average household income of that specific group of livelihood type. Average ecosystem service dependency varies by livelihood type (Table 4).

Table 4: Livelihood type baseline dependence on ecosystem services ordered by highest to lowest overall dependence. Specific ecosystem service dependencies (ESDs) (Agriculture, orchard, livestock and natural forest) are the average dependence on each specific service for each livelihood activity across the regional survey population. Overall ESD is the average ESD for each livelihood activity across the regional survey population.

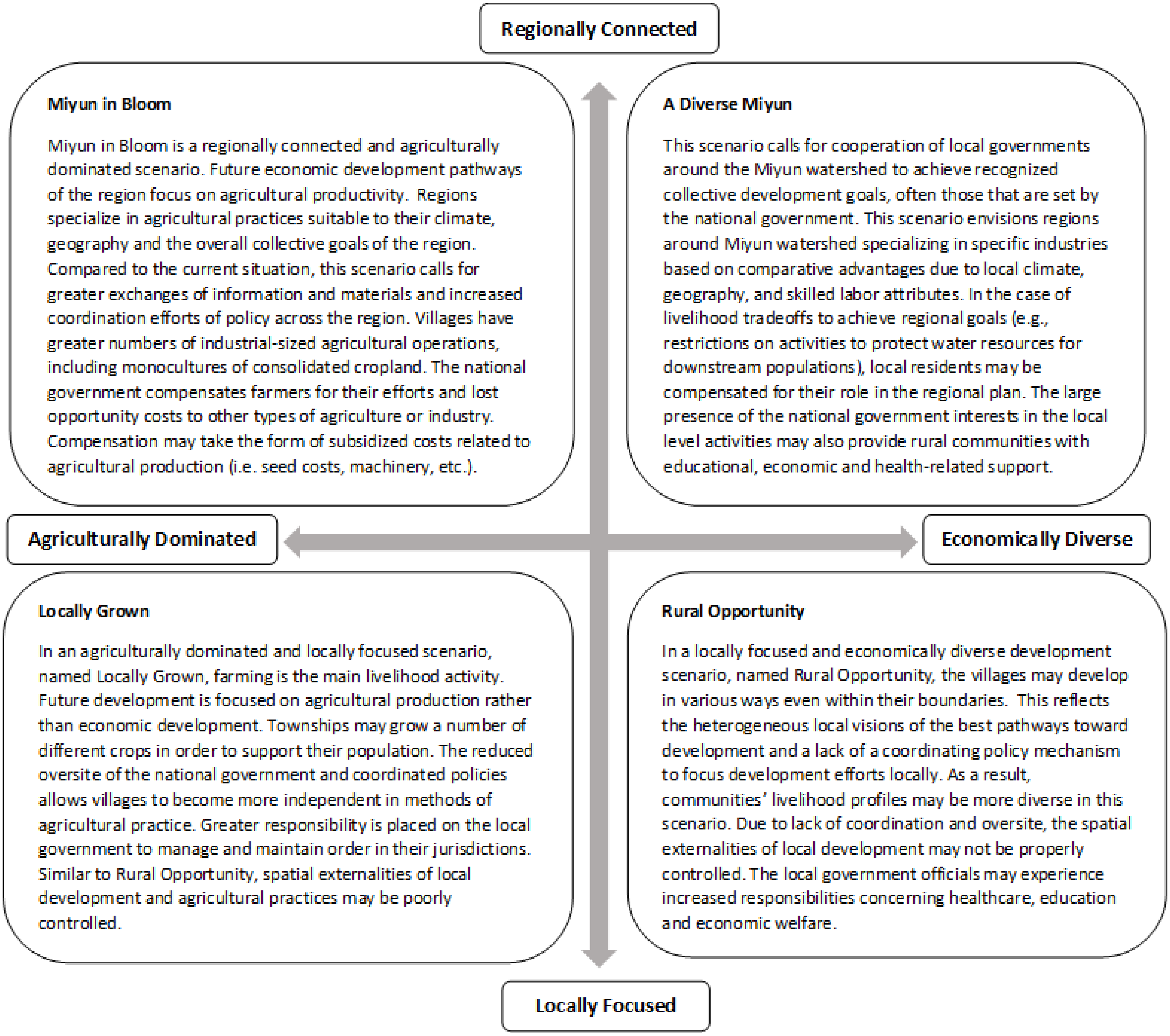
	Averaged specific ESD			
Livelihood activity	Natural forest	Agriculture	Orchard	Livestock
Tourism	1.55%	0.05%	3.24%	0.02%
Farmer	5.95%	2.37%	0.66%	0.37%
Unemployed	5.49%	0.93%	0.00%	0.03%
Retired	1.62%	1.98%	1.80%	0.04%
Government	0.94%	0.00%	0.02%	0.00%
Herder	1.58%	0.86%	0.73%	1.53%
Blue collar	1.17%	0.48%	0.18%	0.06%
Commercial	3.74%	0.64%	0.81%	0.00%
Teacher	0.33%	0.00%	0.00%	0.00%
Student	1.41%	0.00%	0.00%	0.00%
Service	0.91%	0.00%	0.00%	0.24%
Transportation	0.96%	0.08%	0.81%	0.00%

4.5.2 Scenario planning

Total number of participants present was 42; each site had approximately ten participants per workshop. The approximate average age range of all participants was between 45-60 years old and generally, male participants dominated the workshops.

The first visit of the poly-workshop scenario planning approach resulted in ranked lists of drivers of change from the villages. Each village developed a list of about 8-10 drivers of change. The outcome of the first visit to each village resulted in ranked historical drivers of change. The top two drivers across all villages were governance level and economic development. Participants created village-specific narratives of each regional scenario for 20 years into the future. We synthesized these into four regional scenarios namely, *A Diverse Miyun*, *Rural Opportunity*, *Locally Grown* and *Miyun in Bloom*, discussed below (Figure 8).

Figure 8: Scenario axes diagram and scenario conditions (Adapted from Figure 4 in Chapter 3).



A Diverse Miyun is a regionally connected and economically diverse scenario where there are greater exchanges of information and materials across the region, and regions specialize in industries suitable to their climate, geography and skilled labor characteristics. *Rural Opportunity* is a locally focused and economically diverse scenario where towns are more independent from higher levels of government and self-sufficient and the types of jobs increase in each location. In the economically diverse scenarios we might expect decreases in ecosystem service dependency because local and regional economies will become more diversified and tend to focus on service sector, transportation and infrastructure employment.

Locally Grown is a locally focused and agriculturally dominated scenario where local governments have greater responsibility as the national government reduces oversight; farming is the main source of livelihood and villages focus on increasing agricultural production and efficiency. *Miyun in Bloom* is a regionally connected and agriculturally dominated scenario where the national government coordinates transportation, information technology and material flow across the region, villages have greater numbers of industrial-sized agricultural operations, including monocultures of consolidated cropland and receive subsidies from the national government. In the agriculturally dominated scenarios we would expect to see increases in ecosystem service dependency because economic development is focused on agricultural production, and processing agricultural products and therefore, households would be increasingly reliant on agricultural products from farmland, orchards and livestock resources.

The second visit of the poly-workshop scenario planning approach resulted in many components of village specific approaches to reach regional scenario futures. Villages differed in the specific process they would take to achieve the development conditions described in each regional scenario. Local geographies, established skill-sets, climate and a number of other factors influence the specific processes villages engage in to reach scenario futures. For example the residents of Village B, the most remote of the three study villages, said they would continue to engage in agricultural activities in the economically diverse regional scenarios. We focus on the village scenario future changes in population proportion of livelihood activities.

4.5.3 Scenario livelihood type changes

Participants reported percent changes in proportions of livelihood types for each scenario (Appendix 3). Villages differ in the specific proportion changes in scenario livelihood activities. For simplicity we report on changes in scenario livelihood types greater than 10 percent change in future livelihood type proportions (Appendix 4).

In general, we find a greater magnitude of changes in proportion of livelihood types across all study villages in the economically diverse scenarios (*A Diverse Miyun* and *Rural Opportunity*), implying the economically diverse scenarios may experience changes in population skillsets. We find notable increases in proportion of herder livelihood types in the agriculturally dominated scenarios (*Miyun in Bloom* and *Locally Grown*), revealing an increased possibility of animal husbandry in future scenarios focused on agriculture.

4.5.4 Future change in ecosystem service dependence

Our estimates of future village-level dependence on ecosystem services is directly related to the change in livelihood categories since we multiply the change in livelihood type by its baseline dependency measure from survey data. We first report on the general shifts in ecosystem service dependency across scenario then describe specific changes in village livelihood type ecosystem service dependencies. We hypothesized ecosystem service dependency would be higher in the agriculturally dominated scenarios (*Miyun in Bloom* and *Locally Grown*) and lower in the economically diverse scenarios (*A Diverse Miyun* and *Rural Opportunity*). However, our hypothesis is disproved in the locally focused scenarios. In the locally focused scenarios net change ecosystem service dependency across all study villages is not what we would expect.

4.5.5 Regionally connected scenario ecosystem service dependency measures - Expected

In the scenarios where development is focused on agricultural production ecosystem service dependency is expected to increase because households will be increasingly reliant on agricultural orchard and livestock resources for their livelihood strategies in these future scenarios. In the economically diversified scenarios dependency on ecosystem services is expected to decrease. Figure 9 shows changes in ecosystem service dependency for livelihood types within each village scenario (bars) along with the net change in ecosystem service dependency of all livelihood types by village scenario (circles). We find the changes in ecosystem service dependency of the regionally connected scenarios is what we might expect because in *A Diverse Miyun* ecosystem service dependency decreases in all villages and this is a scenario focused on diverse economic development and not on agricultural production, therefore, fewer people are involved in agricultural activities and overall dependency on ecosystem services decreases.

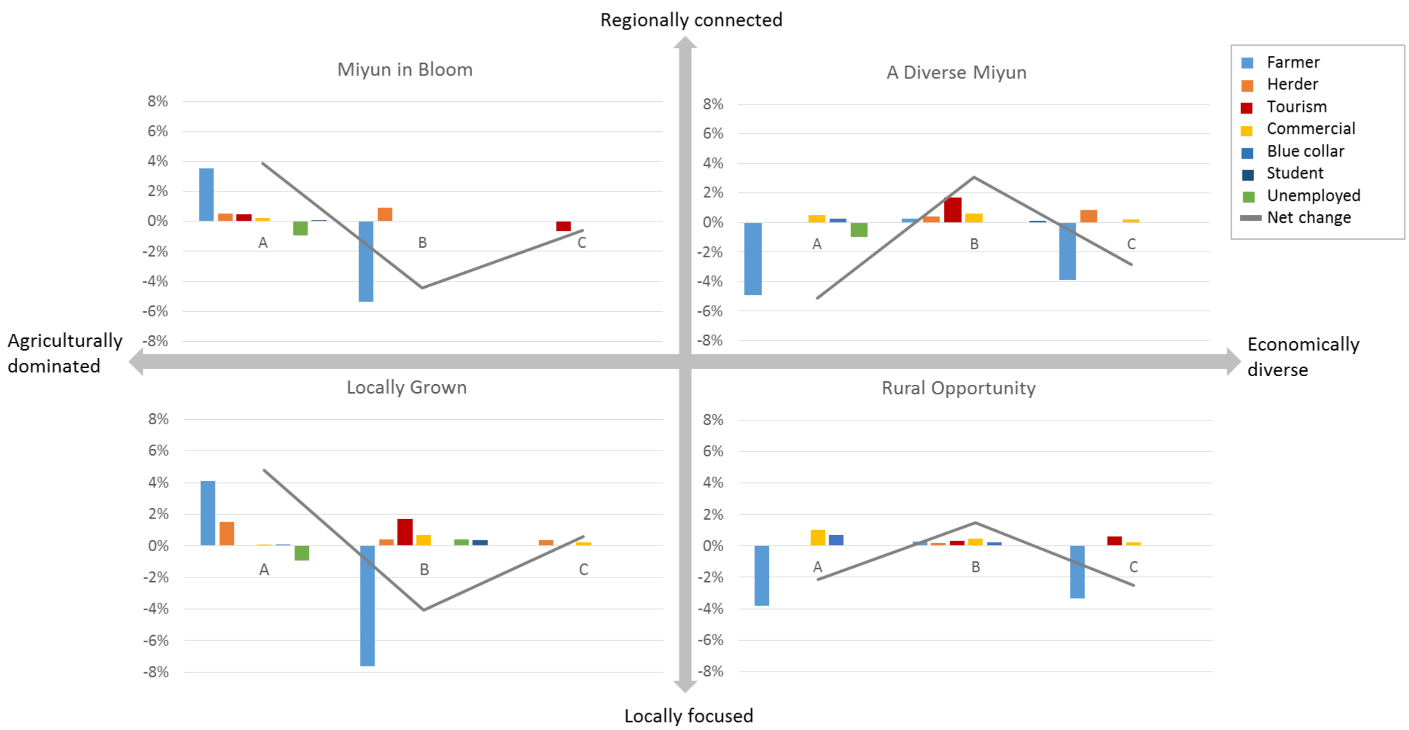
In the second regionally connected scenario, *Miyun in Bloom*, the region again coordinates efforts to achieve regional development goals focused on agricultural services (i.e. production, processing, etc.). In this scenario, we expected an increase in dependency on ecosystem services due to the scenario's conditions noting an increase in agricultural activities and production.

4.6.6 Locally focused scenario ecosystem service dependency measures- Unexpected

In the locally focused scenarios (*Rural Opportunity* and *Locally Grown*) we expected similar trends as mentioned above— decreases in ecosystem service dependency in economically diverse scenarios, Increases in ecosystem service dependency in agriculturally dominated scenarios). However, in the locally focused economically diverse scenario, *Rural Opportunity*, village B experiences a net increase in ecosystem service dependency. Net changes in ecosystem service dependency can be explained for the most part by examining proportion shift in population of livelihood types. A net increase in ecosystem service dependency in village B's *Rural Opportunity* scenario (economically diverse and locally focused) is found because of the notable increases in proportion populations of commercial, service, herder and student livelihood types. Specifically, the net increase in ecosystem service dependency is attributed to commercial herder and student livelihood types' dependence on natural forest ecosystem services (Appendix 4).

In the locally focused and agriculturally dominated scenario, *Locally Grown,* Village B and C experience a decrease in ecosystem service dependency where we would expect an increase in dependency. Both Village B and C report decreases in the ecosystem service dependency of farmer livelihood types in the agriculturally dominated scenario *Locally Grown* (Figure 9 and Appendix 5) and increases in ecosystem service dependency of other livelihood types. Changes in ecosystem service dependency can occur when village scenario changes in livelihood type population proportions. For example, Village C experiences a decrease in ecosystem service dependency in an agriculturally dominated scenario, *Locally Grown*, because of its notable decrease in proportion of farmer livelihood type (Figure 9).

Figure 9: Livelihood type change in overall ecosystem service dependency is shown here for each village scenario. Ecosystem service dependency behaves as we might expect in the regionally connected scenarios (i.e. ecosystem service dependency increases in agriculturally dominated scenario (*Miyun in Bloom*) and decreases in economically diverse scenario (*A Diverse Miyun*)).



4.7 Discussion

Scenario planning methodology allows for the incorporation of uncertainty and participatory knowledge of local and external factors of change experienced and learned by local user groups. The scenario planning approach is suitable for our goals of learning plausible future states of three villages in the Miyun watershed. Future livelihood dependencies on ecosystem services can inform on future shifts in the direct use of ecosystem services and the possible winner and loser user groups of ecosystem services. We built upon baseline ecosystem service dependency measures from a 2014, 2015 household livelihood survey to derive future ecosystem service dependency measures for the various livelihood types of village A, B and C of the Miyun watershed, China.

This research provides a new approach to identify plausible future changes in human dependence on livelihood activities that rely heavily on ecosystem services (i.e. agriculture, livestock, economic forest and natural forest). We determined baseline ecosystem service dependency measures by livelihood type, and we classified households as a specific livelihood type if they spent greater than 30 percent of their time engaged in that specific activity.

The baseline ecosystem service dependency results reflect similar findings in forest dependency literature. We found unemployed livelihood types have the third highest baseline ecosystem service dependencies. This is most likely due to their lack of annual income and reported collection of natural resources for either subsistence or sale. In the forest dependency literature low income groups often have the highest dependency on natural resources or derive a majority of their earnings from ecosystem services (Vedeld et al., 2007, Angelsen et al., 2014).

All villages experience trade-offs in each scenario. In agriculturally dominated scenarios where farmer livelihood types experience decreases in dependency on agriculture, orchards, forest and livestock (Appendix 5 Village B, *Locally Grown*), local governments experience trade-offs in agricultural production and a less experienced work force for an increase in commercial and service activities which may bring the village more revenue.

Changes in livelihoods and ecosystem service dependency show resilience to likely development trends. Villages' specific attributes (e.g. residents' skillsets and historical knowledge of local conditions) and their dependence on ecological systems contribute to levels of resilience (Adger 2000). Village A has diverse groups of livelihood types. In *A Diverse Miyun* farmers decreases but there are notable increases in blue collar, commercial and transportation (Appendix 3). Because Village A is familiar with these industries and it experiences relatively high increases in these livelihood types, compared to villages B and C, it may be more resilient than other study villages to development trends projected in this scenario.

We found changes in ecosystem service dependency aligned with our hypothesis in the regionally connected scenarios. Ecosystem service dependency change in the locally focused scenarios behaved more heterogeneously than what we expected. This may be because the locally focused scenarios called for more local government autonomy in the future development of their village. This finding shows that given a regionally shared vision for the future, when sub-regions are provided independent decision-making power their processes for reaching the regional scenario may be different than what the regional-leaders expected. If this is the case, it may benefit land use managers and policymakers to be more involved in sub-regional decision-making so as to reduce the risk of unexpected outcomes from regional planning decisions.

4.8 Conclusion

Our approach to exploring plausible future ecosystem service dependency measures of village livelihood types around the Miyun watershed combines participatory scenario planning and household livelihood survey data. This work aims to lay the foundations for future ecosystem service dependency measurements of rural populations. We acknowledge the results found are based on plausible future scenarios from participant narratives but the findings offer insight to how researchers, planners and policy makers can think about future human demand for ecosystem services and the different ways populations may be affected by changes in natural resource supply.

Examining plausible future changes in ecosystem service dependency of rural populations can build resilience among these communities. Resilience is built in order to be prepared for surprises which may directly or indirectly impact a community. We used scenario planning here as a tool for exploring uncertainty and better prepare for surprises in shifts of natural resource supply.

We examined changes in livelihood dependency on agriculture, orchards, livestock and natural forest ecosystem services according to plausible future regional scenarios created by Villages in the Miyun watershed, China and found heterogeneous changes in ecosystem service dependency in the locally focused scenarios. Plausible future changes in the dependency of certain livelihoods on specific ecosystem services can significantly help natural resource managers in their efforts towards sustainable development and natural resource conservation. If farmer dependency on orchards may increase in a future scenario, targeted management plans can be put in place to protect or expand forest resources that farmers may depend upon.

Chapter 5. Conclusion

This thesis examines the uncertainty surrounding future changes in ecosystem services considered during decision-making processes. Scenario planning is a useful tool to examine future uncertainty of drivers of change. The applicability of this method to exploring scenario changes in village livelihood types provided further insight both into how villages would reach scenario futures, and into the types of activities the population may need to become engaged in. Rural household livelihood activities are diverse, and the households typically depend upon more than one ecosystem service for their livelihoods and sustainability. We examined changes in ecosystem service dependency, by dominant livelihood activity, within each of the various plausible scenario futures. By doing so, we learned how households engaged in different dominant livelihood activities may differ in the extent to which they will be dependent on ecosystem services in the future.

The objectives of this project were met. Chapter 3 examined sub-regional response to regional future scenarios of the Miyun Watershed, China using the poly-workshop scenario planning method. Regional scenarios were created by first learning drivers of change then generating the scenario axes diagram and facilitating scenario narrative creation to develop the final scenario storylines which covered a 20 year time period. The poly-workshop approach contributed to knowledge on plausible adaptive co-management responses to livelihood changes in scenario futures. Chapter 4 identified plausible future changes in the study population’s livelihood activities and corresponding changes in ecosystem service dependency. Future livelihood type vulnerability to plausible future changes in ecosystem services was studied and the findings indicated with more local autonomy sub-regional response to regional changes might not be what regional decision-makers may expect.

5.1 Poly-workshop scenario planning

In the first paper, a poly-workshop scenario planning approach was used in order to better understand sub-regional processes that may shape the Miyun watershed. In contrast to the centralized-workshop approach where regional leaders in business, government and the community are involved in the decision-making process, the poly-workshop approach has the ability to engage local stakeholders who may not necessarily be able to attend the regional workshops for many reasons including travel costs, work schedules, lack of reliable communication and other factors. During the poly-workshop scenario planning exercises, village participants collaborated in discussions about plausible future changes in the proportion of the village population that would be involved in various livelihood activities identified in each of the regional scenarios. The process used in each of the villages produced unique results, thereby highlighting the increasing importance of engaging sub-regional and rural participants in the scenario planning process. Each of the village processes used to reach the Miyun regional futures were unique and produced distinct results. This highlights the benefits of engaging sub-regional and rural participants in the scenario planning process.

There are costs and benefits associated to conducting a poly-workshop scenario planning exercise. One marked advantage to the poly-workshop approach is that it allows for the examination of specific sub-regional responses to regional scenario development trajectories. The poly-workshop method is useful when research questions surrounding scenarios involve specific changes in people's livelihoods or impacts on ecosystem services which people in the study area are dependent on. The centralized-workshop scenario planning approach is mainly focused on the collaboration of regional stakeholders in a single location.

The main disadvantage to poly-workshop scenario planning are the costs associated with number of visits and travel time. The poly-workshop process involved making two visits to sub-regional locations, three villages around the Miyun watershed, in order to complete the scenario planning workshops. In total there were six trips to complete the scenario workshops. The first visit to all three villages took one and a half days to complete with about 2 hours spent at each village and about 2 hours travel time between each village. The poly-workshop approach is likely unnecessary if the research objective is solely to develop regional visions of the future. However, if the research objective pertains to specific local variation in response to regional scenarios the poly-workshop approach may be better suited than the centralized-workshop approach.

The poly-workshop approach can inform policy-makers on the strengths and weaknesses of each region (i.e. skillsets, climatic, soil quality or water resource availability) from regional development scenarios. Further, it can provide a helpful introduction to implementation of adaptive co-management strategies for the region. As a result of adaptive co-management, sub-regional responses to regional development scenarios might be considered alongside various regional stakeholders, major policies developed by government, and economic goals of businesses.

5.2 Future ecosystem service dependency

The changes in ecosystem service dependency for livelihood types were informed by baseline dependency measures from a previous household survey (Robinson, in preparation) and the scenario changes in livelihood type populations. In the regionally connected scenarios, changes in ecosystem service dependency behaved expectedly – dependency increased in the agriculturally dominated scenarios and decreased in the economic development scenarios. Conversely, the locally focused scenarios behaved heterogeneously in terms of changes in ecosystem service dependency. Ecosystem service dependency decreased in *Locally Grown*, an agriculturally-dominated scenario, and ecosystem service dependency increased in *Rural Opportunity*, an economically dominated scenario.

The plausible future ecosystem service dependency measures reveal possible livelihood resilience to regional scenario development trajectories. The results indicate dependency on ecosystem services may increase in agriculturally dominated scenarios. From this, targeted policies can be created to protect resources that people depend on. The results provide further opportunities for researchers and planners to think about how development scenarios may impact social-ecological systems, livelihood resilience and community well-being. As there is further research into ecosystem service dependency, there will be challenges regarding best measurement practices and the best means for incorporating outcomes into institutions and policies which promote livelihood sustainability and resilience to inevitable future change.

5.3 Summary

The findings reported in each main paper contribute to the scenario planning literature, highlighting the diverse applicability of the systematic methods used to exploring future uncertainty. The poly-workshop approach accounted for smallholder voices and provided insight on the specific processes each sub-region would take to reach regional futures. Scenario planning was used to examine future ecosystem service dependency measures of livelihood types within the three study villages. These measures may help to inform plausible scenario ecosystem service demands, and livelihood resilience to future uncertainty, for those living with the Miyun watershed.

This thesis provides a greater understanding of the plausible future development trajectories of the Miyun watershed, how those future changes may affect the livelihood activities of sub-regional populations and the subsequent vulnerability to changes in ecosystem services. The implications of this research lie in its applicability of its methods and results to other situations where it is necessary to ensure adaptive responses to likely regional development trajectories. It provides researchers, planners and decision-makers with a social-ecological systems approach to examining sub-regional population response, livelihood resilience, and community well-being in the face of environmental change.

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Appendices

Appendix 1a: Village recorded changes in livelihood capital for each scenario. Items within a livelihood capital category were ranked on Likert scale of becoming "much worse" to "much better" then translated to a numeric scale of -1 to 1.

Qualitative response	Code
Much better	1
Better	0.5
No change	0
Worse	-0.5
Much worse	-1

Appendix 1b: During the second visit of the scenario planning workshops (Figure 3, step 3, subset 1) we asked focus groups how specific themes might change in each scenario. The specific themes are listed in Appendix 1b. The research team then categorized the specific themes into the five sustainable livelihood capitals: natural capital, financial capital, physical capital, human capital and social capital presented by Scoones (1998). The focus groups were asked to rank the direction and magnitude of each theme change for the regional scenarios by stating the theme will become much better, better, no change, worse or much worse in a future scenario. The qualitative rankings were translated to a numeric scale of -1 to 1.

The frequency distribution column of Appendix 1b is a visual representation of the frequency of response scenario changes of each theme. Red bars in the frequency of response column should be interpreted as at least one village stated the corresponding theme would become “much worse” in the listed scenario. Red bars are not common. In fact, during the scenario planning exercises some focus groups were reluctant to state themes would become worse. A majority of the frequency bars in the economically diverse scenarios (*A Diverse Miyun* and *Rural Opportunity*) are medium green which translates to “better”. In the agriculturally dominated scenarios (*Locally Grown* and *Miyun in Bloom*) light green (“no change”) and lime green (“worse”) bars are dominant. Analysis was not performed on these results because participants answered on a Likert scale and examining diversity in response of these qualitative answers is not appropriate.

Appendix 1b

	Theme Change							
	A Diverse Miyun				Rural Opportunity			
	A	B	C	Frequency distribution	A	B	C	Frequency distribution
Natural capital								
Air	0.5	0.5	1		-0.5	-0.5	0.5	
Water	0.5	0.5	1		-0.5	-0.5	0.5	
Biodiversity	0	0.5	1		-0.5	-0.5	0.5	
Sloping land conversion program	0.5	0.5	0.5		0	0.5	0	
Paddy land to dry land project	-0.5	0	0		0	0	0	
Natural forest conservation	0.5	1	0.5		0.5	0.5	0	
Returning farmland to forest progı	0.5	1	0.5		0.5	0	0	
Grazing ban	0.5	0.5	0.5		0.5	0.5	0	
Financial Capital								
Assets	0.5	0	0.5		0.5	0.5	0.5	
Income	0.5	0.5	0.5		0.5	0.5	0.5	
Tourism	0	0.5	0.5		0	0.5	0	
Commercial trade	0	0.5	0.5		0.5	0.5	0	
Industry	0	0	0		0.5	0	0	
Agricultural	0.5	0.5	0		-0.5	0	0	
Physical capital								
Roads	0.5	0.5	0.5		1	0.5	0.5	
Irrigation	0.5	0.5	0.5		1	0.5	0	
Electricity	0.5	0.5	0.5		0.5	0.5	0.5	
Home reconstruction project	1	0.5	0.5		1	0.5	0	
Information Technology	0.5	0.5	n/a		0.5	0.5	0	
Farm extension	0.5	0.5	0.5		0	0.5	0	
New Seeds	0.5	0.5	0.5		0	0.5	0	
Human capital								
Health	0.5	0.5	1		-0.5	0.5	-0.5	
Healthcare	0.5	1	0.5		1	0.5	0.5	
Health Insurance	1	1	0.5		1	0.5	0.5	
Welfare	0.5	0.5	0.5		1	0.5	0.5	
Education	0.5	0.5	1		0.5	0.5	0.5	
Skill training	0	0.5	n/a		0.5	0.5	0.5	
Social Capital								
Inequality	0.5	0.5	0		-0.5	-0.5	-1	
Local employment	0.5	0.5	0		0.5	0.5	0.5	
Migration to Beijing	0.5	1	0.5		-0.5	-0.5	-0.5	

Appendix 1 continued

	Theme Change							
	Locally grown				Miyun in Bloom			
	A	B	C	Frequency distribution	A	B	C	Frequency distribution
Natural capital								
Air	-0.5	0	0.5		1	0.5	1	
Water	-0.5	0	0.5		0.5	0.5	1	
Biodiversity	-0.5	0.5	0.5		0.5	0	0	
Sloping land conversion program	-0.5	-0.5	0		1	-1	0	
Paddy land to dry land project	0.5	0	0		0	0	0	
Natural forest conservation	0.5	1	0		0.5	1	0	
Returning farmland to forest program	0.5	0	1		0.5	0	0	
Grazing ban	0.5	-0.5	0.5		0	1	0	
Financial Capital								
Assets	0.5	0.5	-0.5		0.5	0.5	n/a	
Income	0.5	0.5	-0.5		0.5	0.5	0	
Tourism	0.5	0	0.5		0.5	0	0	
Commercial trade	0.5	0.5	0		-0.5	0	0	
Industry	-0.5	0	0		-0.5	0	0	
Agricultural	1	0	0		0.5	1	0	
Physical capital								
Roads	0.5	0.5	-0.5		0.5	0.5	1	
Irrigation	0.5	0.5	-0.5		0	0	1	
Electricity	0.5	0	-0.5		0.5	0	1	
Home reconstruction project	-0.5	-0.5	0		0.5	0.5	1	
Information Technology	1	0.5	0.5		1	0.5	1	
Farm extension	1	0.5	0		1	0.5	0	
New Seeds	1	0.5	0		0.5	0.5	0	
Human capital								
Health	1	0	0.5		0.5	0.5	1	
Healthcare	-0.5	0.5	1		0.5	0.5	1	
Health Insurance	-0.5	-0.5	0.5		1	0.5	1	
Welfare	-0.5	-0.5	1		0.5	0.5	1	
Education	1	0	0.5		0.5	0.5	1	
Skill training	1	0.5	1		0.5	0.5	1	
Social Capital								
Inequality	-0.5	0	-0.5		0	0.5	0	
Local employment	1	0.5	-0.5		1	0	1	
Migration to Beijing	0.5	-0.5	0.5		-0.5	0.5	1	

Appendix 2: Scenario land use change maps derived from stakeholder conversations about plausible future scenario changes.

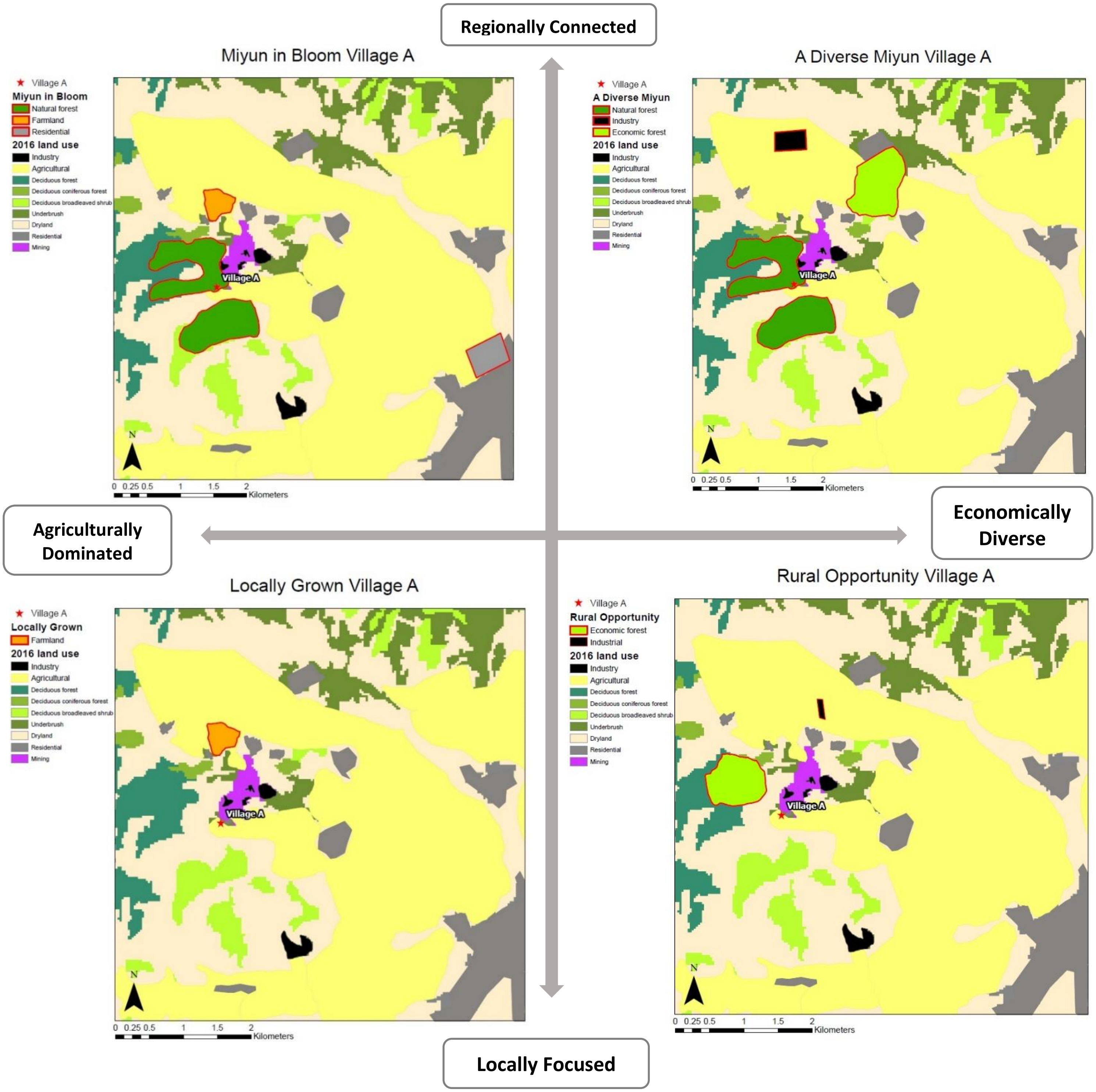
The focus groups were provided with size A1 aerial images of their villages and asked to mark the location and type of land use change for each regional scenario. Focus groups were prompted with questions such as: Given this regional scenario, what might be the land use changes you would expect to see in twenty years? The focus groups used scissors to cut individual, specialized shapes with varying sizes and placed them on the aerial images. Facilitators then worked with focus groups to validate the current land use and learn their ideas on the future land use of the marked area. An example of the resulting focus group exercise is below (Figure 10).

Figure 10: Village C's scenario planning land use focus group exercise for *Locally Grown*

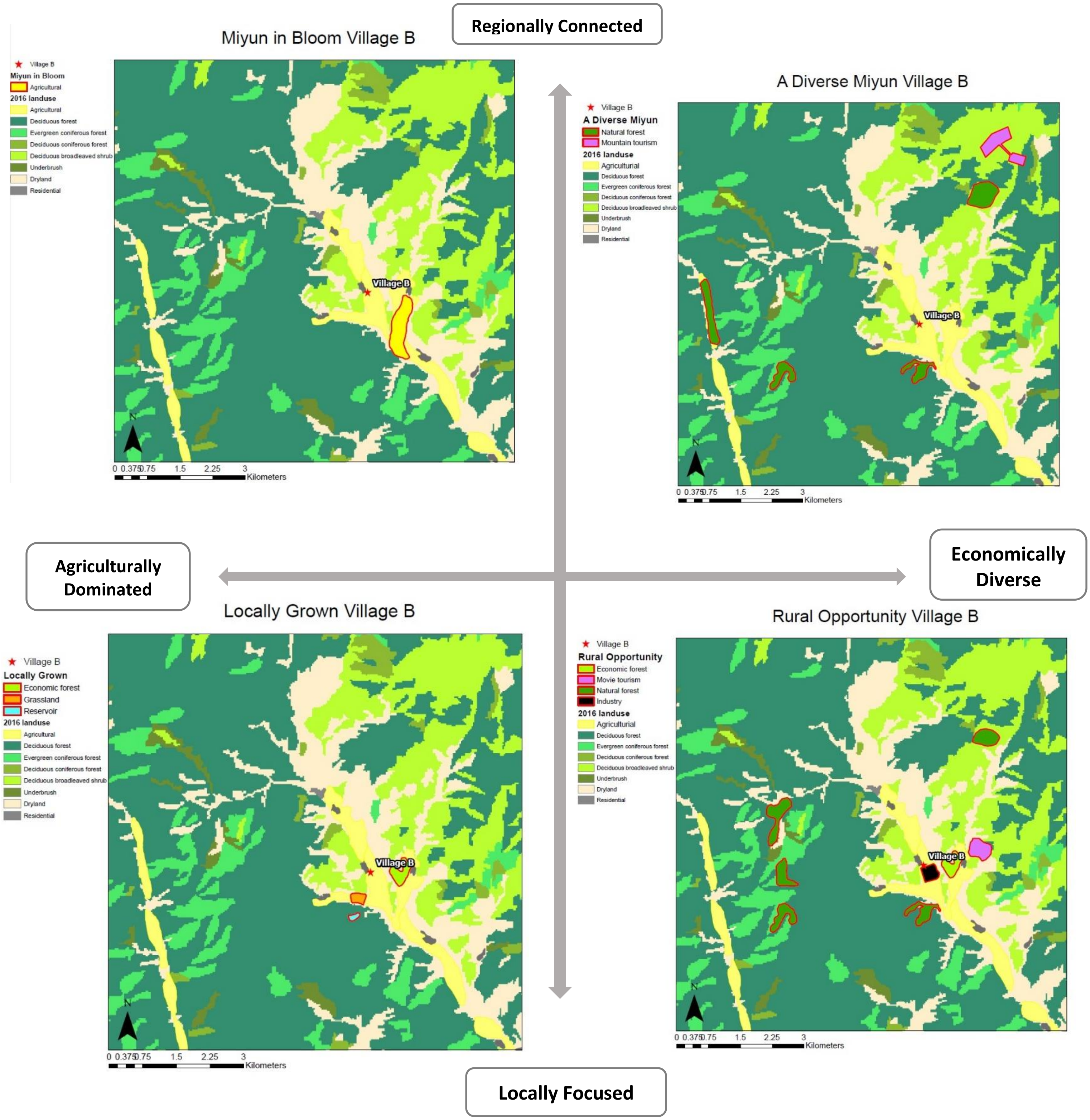
Land use maps of the study villages from 2010 were updated to current land use polygons by creating land use polygons on Google Earth and uploading to the 2010 ArcMap (ESRI 2011) data file. The research team was consulted during this process, making sure to reach consensus on the current land use interpretations from Google Earth. The updated land use maps can be seen as the base-layer of the figures of Appendix 2.

Following the scenario planning workshops, the research team convened to discuss the specific shape of the polygons to be represented on the scenario land use maps. The research team interpreted the shapes and locations of paper placed on the aerial images into plausible polygons. For example, a square natural forest note from the focus groups was placed on top of a mountain (learned after consultation of Google Earth), the research team would then modify the shape of the polygon so that the scenario natural forest land use change would occur on the bottom half of the mountain where the incline is not very steep. Participant feedback was solicited following the creation of the scenario land use polygons. The final outcomes of the scenario planning land use exercise are seen in Appendix 2.

Appendix 2 continued



Appendix 2 continued



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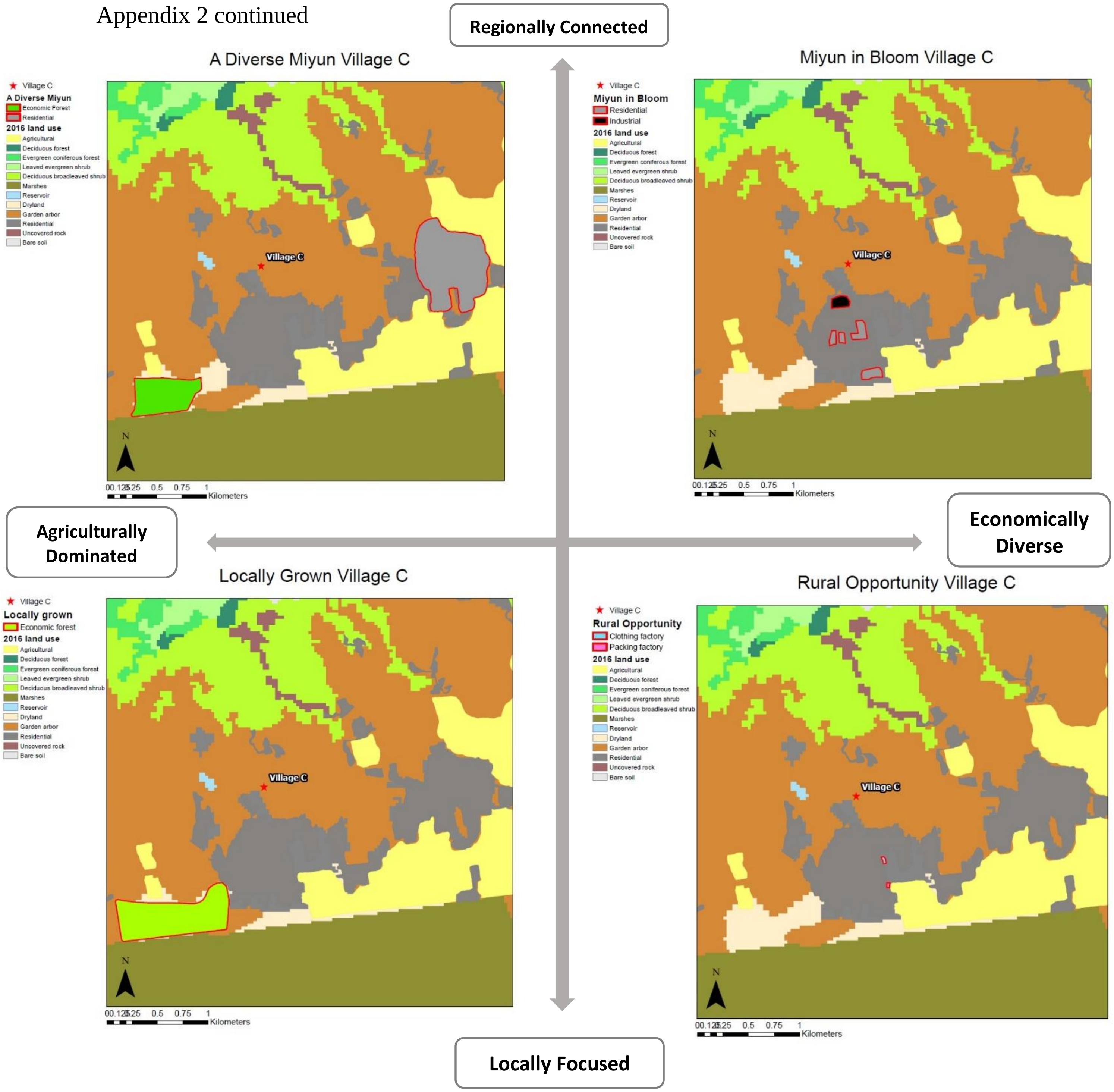


Appendix 3: Percentage change in livelihood types of all village scenarios.

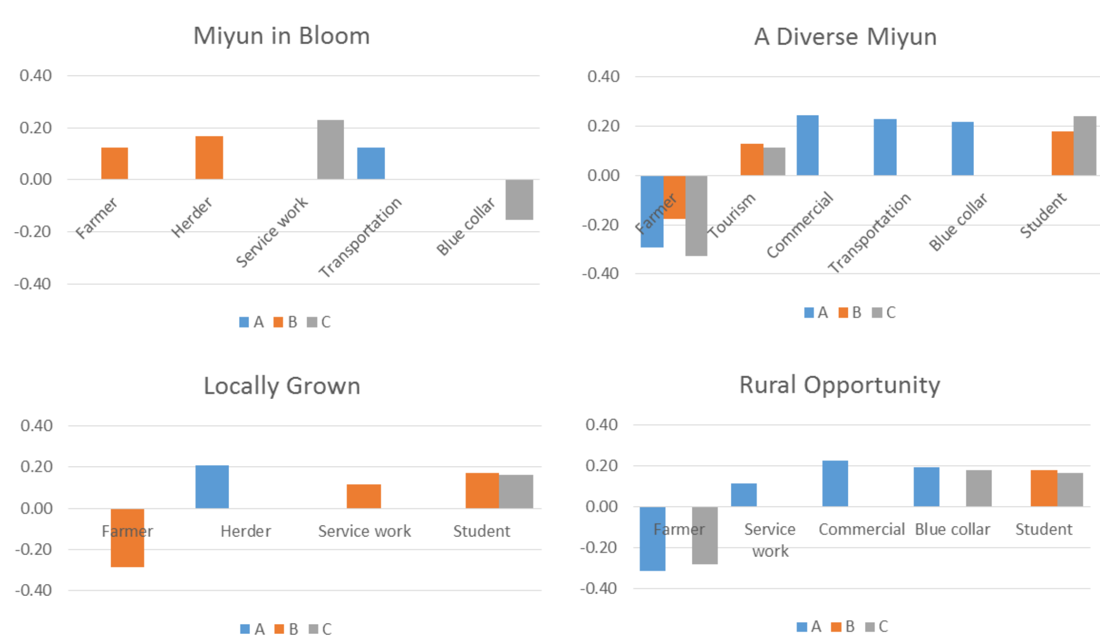
The percent change in livelihood types were central to the results of the future ecosystem service dependency measures. In a sense, the percent changes in livelihood type reflect scenario changes in population of each livelihood type of the study villages. During the scenario planning exercises, facilitators asked focus groups to estimate scenario populations of each livelihood type. The focus groups were given the current percentage of livelihood types of the village's population. This information was gathered from a household survey conducted in the village a few years earlier (Peng et al., in review). The focus groups consulted the baseline livelihood type populations and the short scenario descriptions, and discussed among the group to estimate the future percent of the village's population identified as each livelihood type.

The result of this exercise produced population "become to" percentages. For example, in a given scenario the population of farmer will become to 80 percent. The research team then took the sum of the "become to" population percentages and divided by the "become to" percentage for each livelihood type to ensure scenario populations equaled 100 percent. This work reports on the percent change in population, rather than the future livelihood type population percentages ("become to" percentages), so as to not indicate the future livelihood type percentages are "known". This exercise shows plausible scenario changes in livelihood type population percentage for all village scenarios (Appendix 3). The percent changes in livelihood type populations were then used to determine livelihood type scenario changes ecosystem service dependencies (Figure 7 and Figure 9).

	A Diverse Miyun			Rural Opportunity			Locally Grown			Miyun in Bloom		
Livelihood type	A	B	C	A	B	C	A	B	C	A	B	C
Farmer	-29%	-18%	-33%	-31%	-5%	-28%	9%	-28%	-9%	6%	12%	2%
Herder	0%	6%	0%	0%	3%	0%	21%	4%	0%	7%	17%	0%
Tourism	0%	13%	11%	0%	3%	-1%	0%	10%	3%	3%	0%	0%
Service	0%	4%	2%	11%	2%	1%	3%	12%	8%	7%	0%	23%
Commercial	25%	4%	6%	22%	4%	5%	1%	6%	2%	3%	0%	0%
Blue collar	21%	0%	4%	19%	4%	18%	0%	0%	-3%	-1%	0%	-16%
Transportation	23%	4%	1%	10%	0%	4%	5%	3%	-1%	12%	0%	6%
Student	1%	18%	24%	0%	18%	17%	0%	17%	16%	3%	0%	0%
Teacher	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Government	0%	0%	0%	0%	0%	0%	0%	6%	0%	0%	0%	0%
Retired	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Unemployed	-8%	0%	0%	1%	0%	0%	-8%	0%	0%	-8%	0%	0%

Appendix 4: Greater than ten percent changes in livelihood type ecosystem service dependencies for all village scenarios.

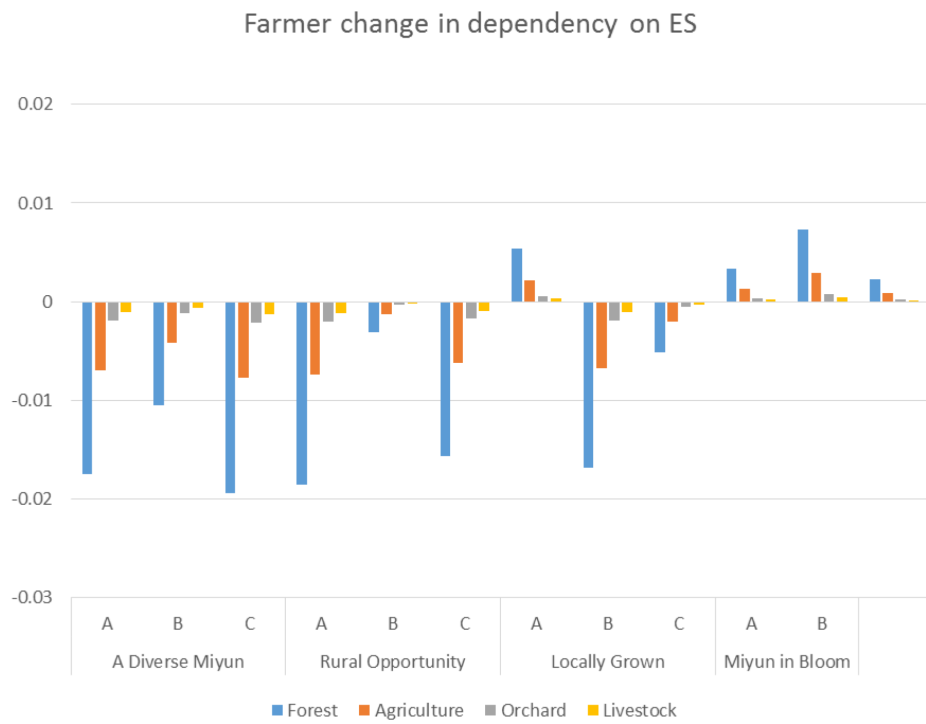
Appendix 4 reports on greater than ten percent change in ecosystem service dependency for livelihood types in order to condense the results for the reader. Further, a less than ten percent change in dependency may not be very noticeable across the 20-year span of the scenarios. Scenario ecosystem dependency changes were determined by multiplying livelihood type population percentage changes (Appendix 3) by baseline ecosystem service dependency measures (Table 4). Villages are distinguished by color and scenarios are presented within the scenario axes diagram. Villages A and C experience decreases in Farmer dependency on ecosystem services in the economically diverse scenarios (*A Diverse Miyun* and *Rural Opportunity*). Village B and C student livelihood types increase dependency on ecosystem service in all scenarios except *Miyun in Bloom*. Village A reports greater increases in dependency in the economically diverse scenarios rather than the agriculturally dominated scenarios. This may be because livelihood types commercial, transportation, and blue collar experience population increases in the economically diverse scenarios (Appendix 3).

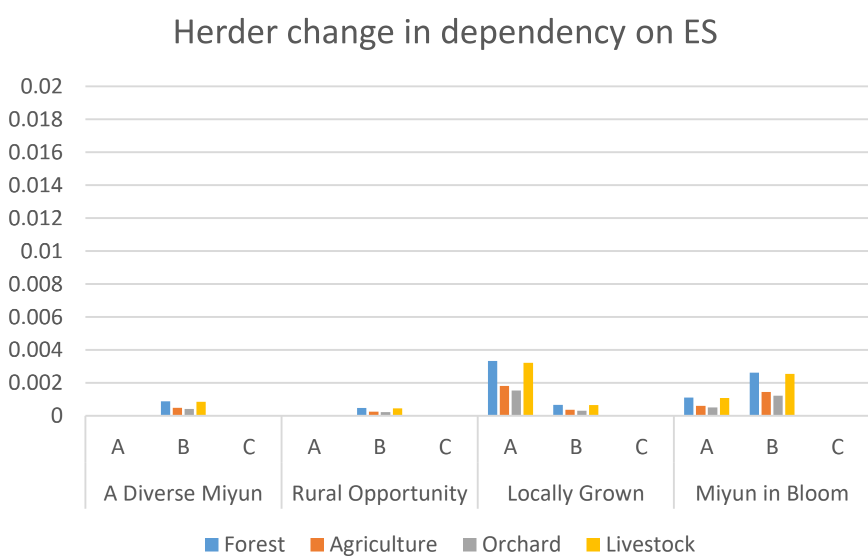


Appendix 5: Percent changes in livelihood type ecosystem service (ES) dependency for specific categories of ecosystem services (agriculture, forest, orchard and livestock).

Appendix 5 shows the livelihood type dependency changes for specific ecosystem services (forest, agriculture, orchard and livestock). These figures are expansions of Appendix 4. Appendix 5 has more detailed information on the changes in dependency for farmers, herders, commercial workers and students for the future Miyun scenarios. The results show farmer dependency on forest ecosystem services fluctuates more than we might expect when compared with changes in agriculture ecosystem services. Farmers might have greater baseline dependencies on forest ecosystem services than they do on agricultural or orchard ecosystem services. Interestingly, Village A and B herders experience increases in dependency in the agriculturally dominated scenarios (*Locally Grown* and *Miyun in Bloom*), which is expected because these scenarios call for economies to be focused on agricultural production and agricultural services. Commercial livelihood types increase dependency on ecosystem services, mainly forest resources, in the economically diverse scenarios (*A Diverse Miyun* and *Rural Opportunity*) and *Locally Grown*. This is likely due to population increases of commercial types in these scenarios. Students show similar trends of increases in dependency on natural forest resources in *A Diverse Miyun*, *Rural Opportunity* and *Locally Grown* for Village B and C. This is likely due to increases in scenario student populations.

Appendix 5 continued





Appendix 5 continued