A Century of Change: Documenting Ecological Landscape Patterns in Northwestern Yunnan

This thesis is submitted to the Faculty of Graduate Studies to partially fulfill the requirements for a Master of Environmental Studies degree offered through the Northern Environments and Cultures Program at Lakehead University

By

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Abstract

This thesis provides a biogeographical analysis of the ecological landscape changes that have occurred in northwestern Yunnan over the past century. The practical purpose of this dissertation is to evaluate the major changes in landscape ecology and suggest causes behind the long-term patterns of ecological landscape change. I determine what effects these changes have had on ecosystem health and biodiversity and use the information that I have attained to create recommendations for conservation policy. By replicating historical landscape photographs taken in northwestern Yunnan, I am able to profile changes to the geographical distribution of land use and vegetation communities. I argue that this methodology – repeat photography- can be used to develop realistic initiatives for conservation and development programs. I contend that the causes of ecosystem degradation and biodiversity loss have been misidentified in contemporary conservation policy. Through landscape rephotography, I determine that the patterns of land use and vegetation communities have been driven by a complex relationship between biological, physical and anthropogenic actors and that many of these environmental variations that are perceived as contemporary conservation threats were actually evident a century ago. I conclude this dissertation by making recommendations for future steps to encourage ecological sustainability in northwestern Yunnan. I address the need for more research and education, specifically in the fields of climate change research and forest regeneration, as well as adaptive co-management for ecosystem monitoring, and conservation. I argue for further 'ground truth' and baseline information to be developed within northwestern Yunnan to ensure that realistic and relevant conservation targets can be developed for this biodiversity hotspot.

Acknowledgements

This thesis would not have been possible without the guidance, support and patience of my primary advisor, Dr. William Wilson. His unending curiosity, expanded mind, and passion for teaching will continue to motivate me throughout my academic journey. I am most grateful to my committee members, Dr. David Kemp and Dr. Todd Randall, for generously donating their time and expertise to guide my academic discovery and provide me with much-needed advice. I would like to acknowledge the Faculty of Graduate Studies and the Faculty of Environmental Studies for their financial support. Further, I would like to thank Robert Moseley of The Nature Conservancy for allowing me to use his research and findings from the Yunnan Great Rivers Project, as well as offer me additional guidance and suggestions.

I would like to express my sincere thanks to my fearless field assistant Laura Profota for her hard work, positive attitude, and perseverance and to Lily Zhang and the XinTuo Ecotourism Company for an amazing adventure, made possible through their hospitality and support. It was a trip of a lifetime!

Last and surly not least, I would like to acknowledge my family and friends. In particular, I convey the warmest regard to my parents, Leslie and Wayne, and my sisters, Laura and Catherine, for their unwavering love and encouragement. I would also like to thank my friends and colleagues, Lindsay McColm, Lesley Kingsmill and Jennifer Surette, for their ears, their advice and their comic relief.

Dedication

This dissertation is dedicated to Leslie Howard Reid: a charismatic teacher, comedian, and devoted outdoorsman.

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1.0 A Call for Conservation Research in Northwestern Yunnan

1.1 Introduction

The purpose of this study is to evaluate major spatial and vegetational changes in landscape ecology that have occurred in the high altitude environments of northwestern Yunnan over the past 100 years. Using repeat photography and in-field identification of land use and vegetation communities, I analyze ecological landscape change over this time. Period analysis includes variations in the locations and altitude of the tree line, dominant tree species, land use patterns, hydrology, and anthropogenic disturbance, among others. I also assess the significance of these changes and the severity of these changes on biodiversity and ecosystem health.

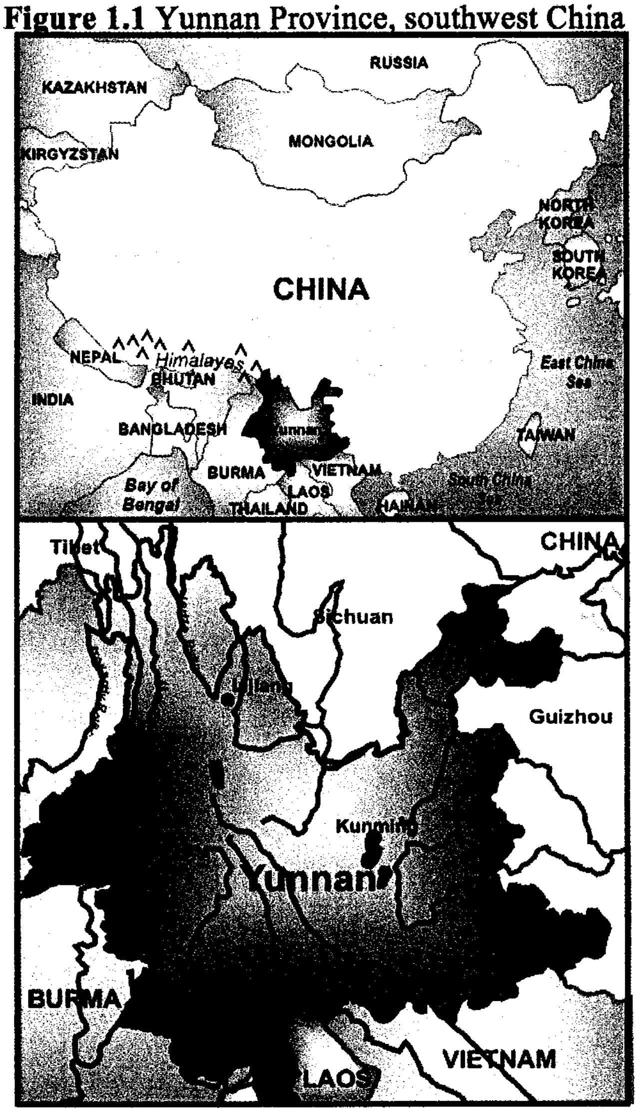
Through conducting this study, I intend to suggest some causes behind long-term patterns of vegetation change. Primarily, I address whether the changes in the frequency and distribution of vegetation communities that have occurred in northwestern Yunnan over the past century have been part of a global process, primarily attributed to the climatic warming of the area, or whether they have been caused by more localized, unsustainable anthropogenic interference to the natural environment. The conclusions of this project will contribute to the much-needed body of scientific knowledge concerning the environmental sustainability of the area. This study, along with others, can aid in the creation of informed conservation policy.

My research is focused on three primary goals that have been developed to respond to my research questions. First, I clarify the degree to which the borders of the vegetation communities and types of land use have shifted over the past century. Second, I determine the ecological significance of the land use changes that have occurred over the past 100 years. In addressing this question, I also specifically focus on the danger that these changes pose to biodiversity and ecosystem health. Finally, I address the factors that have contributed to the vegetation changes that have occurred over the past century and discuss what can be done to lessen any threat to biodiversity and improve ecosystem health.

1.2 Northwestern Yunnan – An Introduction

The northwestern portion of Yunnan Province, located in southwestern China, has been called a "hot spot" for its biological and cultural diversity (Myers et al., 2000). This region is located on the most eastern block of the Himalayas where elevations change rapidly as narrow mountain ranges descend to parallel river systems. Within northwestern Yunnan, four of the greatest rivers in Asia - the Irrawaddy, Salween, Mekong, and Yangtze (Jinsha) - run parallel, from north to south, winding through steep gorges up to 3000 meters deep. The rivers cut through glaciated mountain ranges that tower over 6500 meters above sea level. The complicated topography seen in northwestern Yunnan can be attributed to the geological history of the area. The collision of the Indian and the Eurasian tectonic plates prompted the closure of the Tethys Sea and the uplift of the Himalayan Range. Northwestern Yunnan continues to

Figure 1.1 Yunnan Province, southwest China



be an area of tectonic activity, as it rests on the convergent (destructive) boundary of these two tectonic plates. A combination of topography, geology and climatic effects creates an extremely diversified landscape composed of specialized vegetation communities with narrow distributions (Xu & Melick, 2007). The ecological landscapes range from dry valley grasslands, to deciduous and evergreen forests, to the alpine mosaics reaching elevations above 6500m (Wilkes et al., 2006). The human population of northwestern Yunnan exceeds three million people and is culturally diverse. Eleven ethnic minority groups occupy this region (Moseley, 2006). Their livelihoods are dependent on the sustainable utilization of the local natural resources available.

Issues of environmental degradation and land use changes in northwestern Yunnan have drawn international attention (Melick *et al.,* 2006a). Many programs focused on cultural and biological conservation, environmental restoration, and sustainable development have been implemented with the hope of managing these concerns. However, very little direct evidence has been generated to create ecological baselines about the past landscapes of northwestern Yunnan. Despite the shortage of research, conservation and restoration programs are creating agendas based on assumptions concerning past vegetation communities, rates of change, and patterns of anthropogenic disturbance. It is imperative that more direct fieldwork be conducted as a means of providing some 'ground truth' for the assumptions that are being translated into conservation policy.

Preliminary scientific studies focusing on northwestern Yunnan have suggested several driving forces contributing to biodiversity loss and environmental degradation. Primary among these are local population growth and increasing consumption of agricultural products, timber, and non-timber forest products (Xu & Wilkes, 2004). Also, market forces and past government policies are thought to be partially responsible for the overexploitation of natural resources and biodiversity loss (Xu & Wilkes, 2002). However, other studies discount these factors as being only minor threats to ecosystem health. Instead, many cite global climate change as being the principal factor influencing the landscape changes that have occurred in the high-altitude regions of northwestern Yunnan over the past century (Moseley, 2006). There is considerable disagreement regarding the driving forces responsible for environmental degradation in northwestern Yunnan.

1.3 Definition of Terms

The nature and degree of change represented in the present landscape can only really be appreciated if we know what preceded it. Historical Ecology unites ecology and historical geography and can contribute to that knowledge. It explores ecological landscapes from the past that have been lost, or severely degraded (Egan & Howell, 2001), and it requires a series of empirical measurements and observations through time to gather valuable practical information about fluctuations in population, ecosystem health, disturbance events, and rates of process (Swetnam et al., 1999). In northwestern Yunnan, historical profiles that document the ecological landscape over the past hundred years would provide a scale that could effectively inform conservation policy. Information about this time period would allow for improved assessment of past threats to biodiversity, ecosystem health, and land use changes, and an improved ability to determine relevant and realistic objectives for conservation programs. Assessing the ecological landscape over the past hundred years allows for dependable indicators to be established for measuring the possible threats to the biodiversity of the region. These indicators will allow researchers to interpret the natural land use patterns in an ecological landscape over time.

Northwestern Yunnan has had very little scientific research conducted that analyzes the ecological landscape changes that have occurred over the past century. Yet, over the past one hundred years, northwestern Yunnan has drawn plant hunters, botanical enthusiasts, and scholars who explored its unique natural environment. Descriptions of the historical landscapes of northwestern Yunnan have been recorded within published books, journal articles and personal writings, as well as landscape photographs. These resources provide adequate information to reconstruct the past ecological landscape and evaluate the landscape changes that have occurred between these records and the present day.

Historical photographs, in particular, provide straightforward physical data of past ecological landscapes. By comparing historical photographs with ones taken at present from the same location, patterns can be detected, as well as trends in landscape process. *Repeat photography* is the comparison of old photographs with newer ones taken in the same location. Tom Swetnam *et al.* explain repeat photography as a "simple, inexpensive, and elegant tool for reconstructing past environmental changes and for monitoring future ones" (1999, p. 1196). It is an extremely quick and effective method of documenting changing vegetation patterns (Hall, 2002). Fixed-point, time-lapse photography was first employed as a method to study landscape changes by Professor S. Finsterwalder in 1888 as a tool for mapping glacial changes in the eastern Alps over time (Skovlin *et al.,* 2001; Webb, 1996). Since then, repeat photography has been used all over the world to document temporal vegetation changes (Turner, 1990; Webb, 1996). It has proven to be a reliable tool for ecologists studying ecological landscape change. To interpret the information revealed through repeat photography, however, a good understanding of landscape and ecological processes – combined in the concept of landscape ecology – is required.

Whereas *ecosystem ecology* concentrates on the cycling of nutrients and energy through an environment, *landscape ecology* examines the ecological consequences of the spatial arrangement of the environment combined into a geographic sphere of analysis (Farina et al., 2005). *Landscapes* are viewed as spatial and temporal mosaics in which combinations of certain ecosystem types and land use practices are common throughout a geographic range spanning kilometers (Forman, 1995). Within a landscape, several characteristics tend to be uniform, such as geomorphology, types of local fauna and vegetation, land use practices, and natural, as well as anthropogenic disturbance patterns (Forman, 1995). Landscapes demand ecological unity and are repeated clusters of spatial patterns (Forman, 1995). *Ecosystems* provide the arena for the complex interactions that occur between the biotic and abiotic elements of the environment. Rowe (1992) describes the ecosystem concept as being three dimensional, combining both the physical and biological realms into a holistic notion. Ecosystem structure relies heavily on the levels of nutrients, moisture and energy available, as well as the degree of disturbance. Ecosystems vary significantly in spatial extent, some occurring at the microbial level, while others span the globe (Cleland *et al.,* 1997).

The landscapes in northwestern Yunnan are known to have a significant number of rare and endangered species, as well as a high level of biodiversity (Tang *et al.,* 2006) *Biodiversity*[1] refers to the number of species that coexist in a particular region (Rapport, 1998). The high-altitude ecosystems of northwestern Yunnan are recognized as being

[1] For the purpose of this thesis, this rather basic definition of biodiversity serves well; however, I acknowledge the shortcomings of this definition. The different types of biodiversity are not distinguished within this thesis, specifically *alpha diversity* (local diversity), *beta diversity* (species turnover), and *gamma diversity* (regional diversity), nor am I explicitly addressing the various biological levels at which biodiversity can be measured, e.g. population, species, DNA, etc.

incredibly diverse and uncommon (Mittermeier *et al.,* 1999). The alpine and sub-alpine vegetation communities consist of varied forest ecosystems that are located at different altitudes throughout the mountainous environment. From high to low altitude, Xu and Wilkes (n.d.) describe the vegetation distribution as follows: alpine scree, alpine heath and meadow, alpine coniferous forest, deciduous forest, *Quercus* forest, *Pinus* forest, savannah, and evergreen broadleaf forest. Further, the ecological landscape of northwestern Yunnan is extremely fragile. The high altitude ecosystem mosaic is known to have numerous small endemic populations, endangered species, and narrow ecosystem distribution present (Xu and Wilkes, n.d.). These species have a very low tolerance to environmental change, either natural or anthropogenic. Forests cover approximately one third of northwestern Yunnan's total land area. The coniferous forests contain timber important to commercial logging, and the high-altitude forests appearing on steep slopes are essential for ecosystem health, as they control soil erosion, water and nutrient cycles, and are rich in biodiversity.

Ecosystem health can be defined according to several different perspectives. From the biophysical perspective, *ecosystem health* can be thought of as a "system organization, resilience and vigor, as well as the absence of signs of ecosystem distress" (Costanza, 1992, p. 34). A healthy ecosystem should be sustainable and exhibit a degree of stability that makes it resistant to stress (Costanza, 1992). Rapport *et al.* (1998) assesses *ecosystem health* through allocating values of *resilience, vigor* and *organization.* The term *vigor* discusses the "activity, metabolism, or primary productivity" of an ecosystem (Mageau *et al.,* 1995), which includes aspects such as species abundance and fertility. *Organization* addresses the complexity and diversity of interactions between ecosystem parts (Rapport *et al.,* 1998). The definition of *resilience* is quantified according to the ecosystem's ability to sustain its natural functions in the presence of environmental stress (Rapport *et al.,* 1998).

Ecosystem stress can result in significant changes to the biophysical landscape. Commonly, the degradation of a healthy ecosystem is shown through a loss of species diversity, as well as deteriorating productivity, reflected in a drastic decline in population numbers of native biota (Rapport *et al.,* 1998).

When evaluating ecosystem health, it is important to address ecosystems as dynamic entities that never reach equilibrium. Change is a natural and integral element of all ecosystems; however, the natural variation in ecosystem dynamics can be thrown off of its natural oscillation when an environmental change continues with the same trend for an extended period of time, such as the current global warming trends, or when the disturbance is so extensive that the ecosystem cannot recover. The dynamic and non-equilibrium nature of ecosystems is not a new concept; however, this concept creates an appreciation for classifying disturbances with regards to impacts and the subsequent recovery processes (Franklin, 1997).

Because of the complexity and individuality of each ecological landscape, ecosystem health must be addressed and defined for each specific environment. As well, restoration techniques must address the specific needs of the ecosystem. In order to adequately address the environmental issues that are facing northwestern Yunnan, it is imperative that research promoting a scientific understanding of the historical ecological landscape transitions be conducted. A proper understanding of the natural ecosystem dynamics and land use changes in the area is necessary to inform and administer beneficial conservation and land use policy.

My current study is intended to inform conservation policy. Whereas *preservation* is an environmental philosophy that dictates that specific ecosystems be removed from human use, *conservation* accepts that natural resources may be used wisely and sustainably[2]. Conservationists believe that stewardship should be practiced to ensure that a healthy, natural environment exists for future generations. With increasing public awareness concerning the importance of ecological sustainability in ensuring a successful economy, informed conservation policy has the possibility to ensure that ecological landscape changes are not detrimental to ecosystem health or the natural resource base while ensuring that the immediate needs of local populations are being met (Xu *et al.*, 2006).

1.4 **Thesis Structure**

Within this first chapter, I have introduced the purpose of this thesis and the questions that I hope to address through conducting this research. I have also provided definitions to several terms that are used within this study. Chapter Two offers a literature review of the topics highlighted within this thesis, specifically, the biogeography of northwestern Yunnan, the land use changes that have occurred there within recent history, and an introduction to the rationale behind my rephotography study. Chapter Three highlights my methodologies, including my fieldwork and my analysis and interpretation. In Chapter Four, I present the results of my rephotography study and my landscape interpretation. In Chapter 5, I provide a critical examination of the methods that are used to conduct this thesis, as well as a discussion of the results of my fieldwork and analysis. I provide a detailed account of the current conservation issues that I see to be of primary importance within northwestern Yunnan, as well as critique contemporary conservation policies. Based on the results of my fieldwork and analysis, I identify steps to mitigate

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[2] I acknowledge that the discussion between preservation and conservation is very complex and that I chose very simple definitions for each. For this thesis, I am centering my definitions around the direct human use of the landscape: Where preservation prohibits human use of the natural landscape, conservation calls for sustainable direct use of the landscape.

biodiversity loss and promote ecological sustainability. Finally, I highlight the main findings of this thesis and provide suggestions for future research.

2.0 A Review of the Literature

2.1 Introduction

Now that the objectives and research questions of this study have been introduced, this chapter supplies the background information explaining the exceptional biogeography, cultural traditions, and political history of northwestern Yunnan. All of these factors have played a significant role in shaping the present land use and vegetation distribution in the area. This chapter discusses the vulnerability of the vegetation communities in the high altitude environments and the importance of landscape research in these areas to ensure their proper protection. Also, this chapter presents repeat photography as an acceptable method for assessing ecological landscape changes through time and I provide examples of where successful repeat photography studies have been performed in the past. Further, within this chapter, I introduce the plant hunters, botanists, and geographers who explored northwestern Yunnan in the early twentieth century, as it is their photographs and field notes that supply the historical information that makes this research project possible.

2.2 The Biogeography of Northwestern Yunnan

Yunnan, an inland province of southwest China, marks the transitional zones of three unique and distinct geographic areas: the Tibetan Plateau, and the monsoon regions of both eastern and southern Asia (Yang *et al.,* 2004). Northwest Yunnan rests on the most eastern block of the Himalayas, where the Qinghai-Tibet and the Yunnan-Guizhou Plateaus unite (Xu and Wilkes, 2004). The elevations are extremely high, reaching 6740m at the summit of Kagebo peak (Yang *et al.*, 2004). This area has unique geographic features, among them, four major rivers: the Yangtze River, the Mekong River, the Salween River, and the Irrawaddy River. The rivers flow on parallel paths, cutting out narrow mountain chains between themselves with steep elevation gradients, which cause highly diverse landscapes and support a variety of ecosystem types (Xu and Wilkes, 2004). The province spans only 8° of latitude, but because of the synergistic effect produced by northwestern Yunnan's variation in altitude, it includes biogeographic regions of ecosystem types that normally would span 35° of latitude, e.g., from the most southern tip of China to China's north (Yang *et al.,* 2004).

There are many factors that contribute to the area's climate. Because of the warm southern jet stream that blows eastward from India, Yunnan has a warm, arid climate during the winter months. Except for the high-altitude glacial regions, the province's tropical conditions permit the over wintering of several tropical animals and plant species that originate in Indo-China. In the spring, the dry season concludes and the southern monsoon winds converge in Yunnan, initiating the hot, humid summer season. This combination of topography and winds allows species to grow in microclimates well outside their expected latitudinal regions. These factors cause a unique overlapping of vegetation types (Yang *et al.,* 2004).

Yunnan's complicated topography promotes ecosystem variation and high levels of biodiversity. The topography of northwestern Yunnan exhibits a distinct north-south trend, encouraging a latitudinal dispersal of species that results in the overlap of tropical and paleoarctic floral realms. Further, the landscape promotes phenomenon allopatric speciation[3] because physical barriers, specifically rivers and mountains, limit species dispersal from east to west. The result is an unprecedented number of ecosystem types and high biodiversity: Despite the fact that Yunnan is only 4.1% of China's total land area, it is

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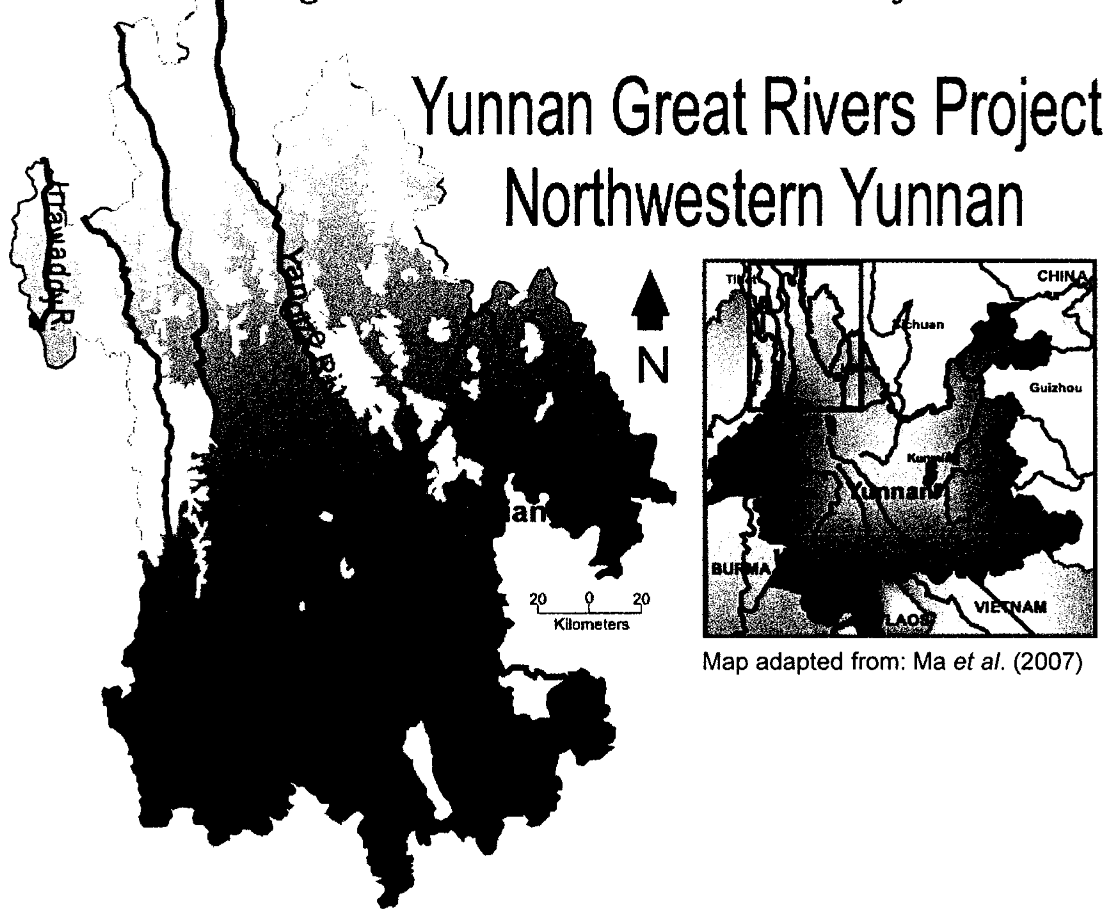
[3] Allopatric speciation (geographic speciation) refers to the extrinsic isolation of species populations. This may result in reproductive (genetic) isolation of that population, creating a new species (Qui *et al.*, 2009).

home to 50% of China's plant seed species, 51.6% of China's high plant species and 54.8% of China's total vertebrate species (Yang *et al.,* 2004). Also, 151 rare and endangered species of plants are found in the province, 42.6% of China's total, and 243 endangered species of animals, 72.5% of China's sum. Yunnan is known throughout the world as a wildlife kingdom (Yang *et al.,* 2004).

The Yunnan Great Rivers Project was a two-year initiative taken on by both the Yunnan Government and the Nature Conservancy to identify the area's most fragile environments and the biggest threats to the native biodiversity (The Nature Conservancy, 2008). This program was introduced to help create a sustainable economic development plan for Yunnan Province. The Yunnan Great Rivers Project was established in 1999 as a collaborative effort between the Chinese government and the Nature Conservancy to prioritize and develop strategies for ecological conservation within northwestern Yunnan. The study area of the YGRP lies on the in the Hengduan Mountains where the upper Yangtze, upper Mekong, upper Salween and the Dulong, an affluent of the Irrawaddy, run parallel within 90km. The area of the YGRP covers 66,000 km^2 and has an elevation range from 700m to 6740m (Ma *et al*., 2007). Included within the project area is the First Bend of the Yangtze. **Figure 2.1** (p. 14) shows the area occupied by the Yunnan Great Rivers Project.

The project's researchers identified ninety-eight endangered species of plants, including species of Liliaceae, Magnooliaceae and Ranunculaceae. They also found 703 endemic plant species (Ma *et al.,* 2007), in families including Asteraceae, Ranunculaceae,

Figure 2.1 The Yunnan Great Rivers Project Area



Map adapted from: Ma *et al.* (2007)

and Scrophulariaceae. Finally, they identified a strong correlation between areas with high levels of endemic species and areas with a large number of endangered species. High-altitude environments are important for both types of plants. In northwestern Yunnan, endangered species are found within several ecosystem types, including evergreen broad-leaf forest, alpine meadow, temperate coniferous forest, and mixed forest. The most important habitats include evergreen broadleaf forest, subalpine meadow, alpine meadow and alpine scree (Ma *et al.*, 2007).

Ma *et al.* (2007) note ten different vegetation types in northwest Yunnan. **Table 2.1** (pg. 15) describes each vegetation community, the dominant species, the significance of each ecosystem and the critical threats to conservation. The alpine mosaic holds the

Table 2.1 A description of the dominant ecosystem types in northwestern Yunnan, the conservation concerns within those ecosystems, and any critical threats. Adopted from Xu and Wilkes (2002).

Ecosystem/Vegetation Types	Representative Species	Conservation Concerns	Critical Threats
Rock, snow, ice, and glaciers (>4800m)	N/A	Difficult to access	• The number of tourists exploring the region via cable car
Scree (>4000-4800m)	*Saussurea spp.* *Fritillaria delavayi* *Meconopsis*	Seldom accessed	• Over collection of medicinal plants
Alpine heath and meadows (3800-4800m)	*Rhododendron spp.* *Salix spp.* *Caragana spp.* *Arenaria polytrichoides*	Many endemic and rare species, ecosystem is easily damaged	• Over-grazing during summer particularly due to increasing pig populations
Alpine conifers - fir and spruce (3000-3800m)	*Picea spp.* *Abies spp.* *Quercus spp.*	Slow-growing, regeneration is difficult once ecosystem is damaged	• The collection of building materials • Grazing pens for livestock • Livestock grazing (understory)
Deciduous Forest (2600-3900m)	*Betula spp.* *Larix spp.* *Populus spp.*	Little known	• Timber (small utensils) • Timber for building of temporary houses • Livestock grazing (understory)
Oak forest - on north-facing slopes (3000-4000m)	*Quercus spp.*	Oaks biodiverse and provide habitat for matsutaki	• Collect oak for livestock bedding
Pine (2500-3500m)	*Pinus yunnanensis* *Pinus densata*		• Timber extraction
Mixed forest - pine and others	*Taxus yunnanensis* *Psuedotsuga forrestii* (indicates a belt of endangered plant species)	*Taxus* bark for marketing	• Timber and fuelwood extraction • Fertilizer collection • Natural forest fires • Pests • Over collection of NTFPs
Savannah (2000-2800m)	*Heteropogon contours* *Terminithia paniculata* *Bauhinia spp.* *Vitex spp.* *Sophora spp.*	Overgrazing	• Collecting stones and sand for construction • Collecting fuelwood
Riparian – evergreen broadleaf and cedar (<2800m)	*Alnus nepalensis*	Fragile ecosystem, regeneration difficult once disturbed	• Collection of building materials, fuelwood and leaves for incense

greatest ecosystem fragility and endemism and has the highest number of rare or endangered species in the region (Xu and Wilkes, 2004). The majority of the land is composed of forest and grassland. The main forest types include evergreen broadleaf and mixed forest. Highland wetlands and lakes are home to numerous endemic species.

Most of the lakes at high altitudes are *sag ponds* that have been created by sinking geological faults, or *morainal* and *glacial erosion lakes* associated with glacial geomorphology. Because these lakes have no connection to each other, each has its own collection of endemic species. Despite the fragility of the ecosystems and number of rare and endemic species in these areas, only a limited number of these unique areas lay within the protection of national park reserves (Xu and Wilkes, 2004).

Alpine ecosystems have been identified as alpine meadow, alpine scree, and cold scrub. Experts agree that all of the mountainous alpine mosaics in the region should be identified as conservation areas (Ma *et al.*, 2007). Because of their species richness, levels of endemism, and the prominence of rare endangered species, it is imperative that these areas be conserved. The Yunnan Great Rivers Project identifies the segmented island alpine region of the southern mountain range as an area of particular significance as these alpine islands are less accessible to scientists and their ecology has not been well explored (Ma *et al.,* 2007). Also, these small alpine islands are experiencing a threat of being lost, as climate change may encourage an ascending shift in ecosystem types.

2.3 Mountain Ecosystems

The United Nations Conference on Environment and Development in 1992 in Rio de Janeiro specifically addressed mountain ecosystems. Mountain environments are significant sources of energy, water, timber and plant products, as well as popular tourist destinations. They also house a high level of biodiversity. The summarized version of Agenda 21/13 from the 1992 United Nations Conference on Environment and Development explains "from the Andes to the Himalayas, and from the Southeast Asia to East and Central Africa, there is serious ecological deterioration. Most mountain areas are experiencing environmental degradation" (Beniston, 2003, p. 5).

In mountainous environments, the vertical dimension – the physical height or altitude, as well as the height of vegetation - is extremely important (Forman, 1995). Additionally, *geomorphic processes* must be taken into consideration within mountainous regions. These processes, such as fluvial and glacial erosion and deposition, plus mass movement, contribute significantly to the ruggedness, "the sum of the slopes, valleys, peaks, exposures, and elevations", of the landscape (Forman, 1995, p. 304).

Mountain environments are important areas for monitoring climate change, as well as evaluating changes related to climatic impacts. Mountains exhibit high ecosystem diversity. This is due to their geomorphology, specifically, steep elevation gradients, and variations in slope and aspect. The climate within mountain regions changes quickly with increasing height; therefore, vegetation, soil structure, and hydrology are affected. Within mountain environments, temperature and precipitation values change rapidly over short distances, promoting ecosystem variation. The rapidly changing abiotic environment promotes the presence of many types of vegetation communities, which are further diversified because the geographic isolation of mountain ecosystems prompts speciation.

High-altitude mountain ecosystems are commonly composed of rare, endemic species because they remain genetically isolated and are not able to spread through the typical continuous latitudinal vegetation corridors that are seen in flatter environments, or at lower mountain altitudes (Beniston, 2003).

Because of Yunnan's complex geography and climate, the region boasts the most diverse and abundant forests ecosystems in Asia, including six types of rainforests, six broad-leaved forests, four coniferous forests, three shrublands, and several other types of ecosystems (Pu *et al.,* 2007). Despite its high levels of endemism and biodiversity, the natural environment of Yunnan is extremely fragile. Because of its small, scattered species populations, narrow areas of ecosystem distribution, and extremely specialized, rare species with poor adaptive capabilities, any environmental disturbance could have catastrophic consequences for Yunnan's unique and valuable biodiversity (Pu *et al.,* 2007).

Climate change may have a dire influence on endemic high-altitude environments. The hydrological cycle could be greatly altered with an increasing global temperature, altering ice, snow, and water patterns. Also, the high levels of biodiversity found in mountainous environments have different thresholds at which they begin to respond to environmental changes. Furthermore, a changing climate will have potentially devastating health consequences to humans, animals, and vegetation as the spread of vector-borne diseases, such as malaria, and pests are known to accompany warming temperatures. Finally, climate change could have a drastic effect on human interests, specifically, agricultural yields and tourism (Beniston, 2003).

2.4 Cultural Diversity and Minority Groups

China's rich cultural diversity is irrefutable. China is home to fifty-five minority groups, the majority of which live in boundary regions or in marginal geographic areas (Xu *et al.,* 2006). Of these 55 minority groups, 25 are present in Yunnan Province[4]. There is a strong positive relationship between the level of biodiversity and the amount of minority cultures that are found in an area (Xu & Ribot, 2004). Although the levels of cultural and biological diversity are strongly dependent on characteristics of natural ecosystems, it also reflects an interaction between nature and social systems. In northwest Yunnan, the conservation of biodiversity has been attributed to the culture and religious beliefs of the minority cultures that inhabit the mountains (Hongmao *et al.* 2002). The indigenous minority groups have deep ancestral roots in the area. These groups have strongly resisted colonization and, although their area is now within Chinese jurisdiction, these minority groups have maintained significant independence (Hongmao *et al.* 2002). Their independence has been aided by the poor rural infrastructure in the region. Many of these indigenous peoples survive through their strong spirituality, deeply rooted in their reverence for nature (Hongmao *et al.* 2002). It has been argued that the close relationship that the local minority groups share with nature has, through their faith, helped ensure the protection of biodiversity in their area (Anderson *et al.,* 2005). Bringing credibility to this Traditional Ecological Knowledge (TEK) may assist in the preservation of this unique natural landscape through time.

[4] The *Minzu Shibie* (Minorities Identification Project) was established in 1949, after the formation of the People's Republic of China, to identify the people who lived within the new borders of China. The criterion for the *Minzu Shibie* was based on a Stalinist model – Ethnic groups were classified based on four factors: a common geographic area, a common linguistic connection, common cultural characteristics, and common economic status. The *Minzu Shibie* classified 55 ethnic minorities within China (Stone-Banks, 2000).

In recent decades, the areas occupied by indigenous minorities have sparked national interest because of the valuable natural resources they contain. New national legislation has been created to govern these marginalized areas, frequently at the cost of indigenous rights and cultural traditions (Xu *et al.,* 2006). The Han Chinese, who make up the national majority, manage the central government of China. They consider themselves to be the most developed cultural group in China in terms of economic and social improvement and, although the government boasts equality among ethnic groups, the Han Chinese believe that it is their responsibility to uplift the minority groups to encourage a cultural tradition towards a more civilized society (Harrell, 1995). The Chinese government wishes to promote economic development and cultural modernization through forcing minority groups to renounce their traditional cultural practices of nomadic herding and agriculture for a more sedentary lifestyle (Xu *et al.,* 2006).

Northwestern Yunnan has a human population of just over three million people (Ma *et al.,* 2007). Most of the population lives in rural areas, with a maximum population density of 24 people per square kilometer. This population density is low in comparison to the rest of Yunnan, 112 people per square kilometer, and especially in comparison to the rest of China, 140 per square kilometer. Most people rely on subsistence farming for their livelihoods. Agricultural production comprises most of their industry, with a significant contribution made by the collection of non-timber natural products from their environment. Tourism, infrastructure for travel, and hydro-electric power are developing rapidly in the area. The majority of the population relies on the natural environment for their housing, food, medicinal needs, fuel, economic wealth, and religious beliefs.

Several anthropogenic factors have been documented as having a negative impact on local biodiversity in Yunnan. Negative drivers include food production, fuel wood extraction, timber procurement, hunting, rare endemic species collection, and livestock grazing (Xu & Wilkes, 2004). These threats have become increasingly harmful as policy, demographic demand, and local and international markets entice the overexploitation of natural resources.

2.5 Land Use Policy in Northwestern Yunnan

It is inevitable that shortfalls will occur in China's environmental policy decisions because the relevant long-term research and fundamental baseline information regarding the landscape in northwestern Yunnan is underdeveloped (Melick *et al.,* 2006a). Because of the rapidly increasing environmental pressures in northwestern Yunnan, the current environmental policy decisions have been rushed. Current policy concerning the preservation of biodiversity highlights the importance of prohibiting people from living on, or using, portions of the landscape. Minority groups in China have been forced off of their traditional lands in order to ensure the preservation of the unique biodiversity. Chinese policy makers believe that the minority groups who inhabit the reserves are a severe threat to biodiversity (Melick *et al.,* 2006a).

Throughout the 1950s and 1960s, China experienced widespread deforestation. Timber harvesting was started to create self-sufficiency among the nation, providing both fuelwood and timber while increasing agricultural lands. However, at present, there are very few old-growth forests in China, and most of the forests in China have been planted in the last 25 years (Ediger & Chen, 2006). Government reforestation programs began in the late 1980s. Currently, widespread subsidies are being offered to convert agricultural land and wastelands into forests.

In 1979, northwestern Yunnan, as well as the rest of China, was greatly affected by the implementation of the Household Responsibility System. This policy transferred the responsibility for land and resource management, which had previously been communal, back to individual households. The main consequence of this transition in northwestern Yunnan was a rapid conversion from croplands to grazing lands for livestock (Xu and Ribot, 2004). This phenomenon is also seen in Tibet. In 1998, The Chinese Government implemented the Natural Forest Protection Program (NFPP) as a measure of environmental protection. This legislation forbade the deforestation of over 30 million hectares of forest within the area of the upper Yangtze River basin and also started several afforestation and reforestation initiatives within northwestern Yunnan. The primary objectives of the Natural Forest Protection Program were to protect the precious watershed of the upper Yangtze, to begin to restore the timber resources of the area that had been depleted, and to protect the recognized biodiversity of the area (Wang *et al.,* 2004). Reforestation programs are usually monocultures, such as pine stands, that don't immediately contribute to the improvement of biodiversity. The scale and concentration of deforestation in northwestern Yunnan was undoubtedly destructive to the native biodiversity, as well as the ecosystem health of the area; however, the logging ban greatly impacted the local minority groups inhabiting northwestern Yunnan who had relied on the forest resources for their livelihoods (Xu and Wilkes, 2004). Logging had been a significant industry in the area since the 1960s and, by the 1990s, the industry was a major employer of the local population, generating more than 80% of the gross income of the area (Hillman, 2003).

In more recent years, the farming communities in northwestern Yunnan have become progressively more vulnerable to both economic and environmental changes. Levels of impoverishment are extremely high in the upland areas of Yunnan Province as their livelihoods are affected by political, economic, and environmental threats (Wilkes, 2006). China has commenced a massive-scale forest protection plan, which includes logging bans and reforestation initiatives, as well as the Sloping Land Conversion Program (SLCP) that intends to return agricultural lands to forests on mountain slopes. The extent of land use change is daunting. The SLCP program plans to convert 14.67 million ha across 25 provinces by 2010. This land use conversion will affect the livelihoods of over 15 million farmers. These plans have been criticized as being too simplistic and one-dimensional, particularly in reference to the diversity of the landscape, the volatility of the ecosystems, and the economic disparity of the local people (Weyerhaeuser *et al.*, 2005).

China's Natural Forest Protection Program (NFPP) and the Sloped Land Conversion Program (SLCP) aim to repair past anthropogenic damage to the environment. The government is providing cash and grain subsidies to farmers who convert cropland into forests. The goal of the SLCP is to convert drastically sloping agricultural land, targeting slopes greater than 25 degrees, into forested land or grassland. These transition projects include reforestation projects to restore the damages of unsustainable deforestation and correct detrimental agricultural practices. These projects have been designed to minimize erosion, lessen the severity of flooding events, and control runoff (Weyerhaeuser & Kahrl, 2006). Although the purpose of these projects is environmentally appropriate, the policies have had drastic implications on the livelihoods of farmers, who do not have the resources or educational tools to rapidly reorient their farming traditions to more lucrative and sustainable practices.

In more recent years, the causes of biodiversity decline have been reevaluated and the suggested causes have shifted from traditional minority groups occupying the area to outside influences, including increasing resource consumption of the urban population, massive agricultural industrialization, national development initiatives, and global climate change. The policy ramifications of removing agropastoralist communities from their traditional lands was responded to in 2003, with the development project 'Enhancing the Livelihoods of Agropastoralists in NW Yunnan', funded by the International Development Research Center (IDRC) of Canada. The primary goal of the project is to assist villagers, traditional farmers, and other stakeholders concerned with the changing policies regarding land use in northwestern Yunnan with developing the appropriate technologies and land use practices to ensure sustainable and comfortable livelihoods for all involved (Wilkes, 2006). Conservation initiatives must shift from the traditional method of anthropogenic exclusion to one where the sustainable practices of indigenous peoples are recognized and rewarded as legitimate sources of biodiversity protection.

This section outlined the changes in land use policies that have occurred since the establishment of the People's Republic of China in 1949. Shortfalls in land use management policies have been a direct result of a lack of baseline scientific information about the natural landscape. With this current study, I hope to contribute baseline scientific information that can be used to better conserve the natural environment of northwestern Yunnan. I will use the method of repeat photography to provide this baseline information.

2.6 Repeat Photography

2.6.1 The History of Repeat Photography

Repeat photography has a lengthy history as a research method. Fixed-point, time-lapse photography was first employed as a method to study landscape changes by Professor S. Finsterwalder in 1888 as a tool for mapping glacial changes in the eastern Alps over time (Skovlin *et al.*, 2001; Webb, 1996). This technique continues to be used to monitor glaciers throughout the world (Pickard, 2002). In addition, repeat photography has evolved to a method of examining temporal ecological landscape changes. It has proven to be a reliable tool for ecologists studying the changes in vegetation over time.

Repeat photography documenting landscape change has been widely used in the United States. The publication of Hastings and Turner's *The Changing Mile* in 1965 introduced repeat photography as a useful tool for monitoring ecological landscape changes over time (Turner *et al.,* 2003). This publication documented the changes in vegetation in the Sonoran Desert due to climate change and the prevalence of domestic grazing. In the United States, scientists have been using repeat photography to record both biotic and abiotic changes specifically related to land use changes and the effect of climate change and significant research using repeat photography has taken place in Colorado (Elliott & Baker, 2004), Northeastern Oregon (Skovlin *et al.*, 2001), and the Grand Canyon (Bowers *et al.,* 1995). These studies have focused on the historical detailing and investigation of ecological landscape changes over time (Webb, 1996).

In more recent years, repeat photography has been used as a method of monitoring landscape changes in Asia. Within the Himalayas, repeat photography studies have been conducted in Nepal and Pakistan (Ives, 1987; Byers, 2005; Nüsser, 2001). Ives and his colleague, Messerli, were the first to employ the method in the southeastern Himalayas of China, exploring both Sichuan and Yunnan provinces (Ives & Messerli, 1984; Ives, 2004; Ives & Messerli, 1989). Northwestern Yunnan became the focus of a repeat photography study in 2001, when the Nature Conservancy began a project to establish historical profiles of the ecological landscapes and land use practices in the area. The Nature Conservancy began an initiative to assess past changes to the landscape using the visual clues available in historical landscape photos until the appropriate empirical data could be collected and assessed. Robert Moseley of the Nature Conservancy asserts that rephotography in northwestern Yunnan will help "to set realistic goals for conservation programs, and to establish reliable methods for measuring conservation successes" (Lassoie & Moseley, 2006, p.141). Since the commencement of this project, numerous publications have emerged assessing the ecological landscape changes that have occurred over the past 100 years using repeat photography (Baker & Moseley, 2007; Lassoie & Moseley, 2006; Moseley, 2006).

2.6.2 Repeat Photography as a Method for Monitoring Landscape Change

The idea of repeat photography seems relatively simple; however, the process is fairly complicated. Photographs should be replicated during the same season and the same time of day. Ideally, the original photograph should be duplicated with the same camera, lenses and film; however, this task is impossible when repeating shots that were taken 100 years ago. As Webb (1996) explains, "repeat photography is a game of getting as close as possible, with perfection being approached only rarely," (p. 37). As well, the time needed to thoroughly document the ecological landscape of a photograph is daunting. Webb (1996) involved several team members during his expedition to document the geologic and vegetation changes that occurred in the Grand Canyon over the past century. Many team members were specialized in the art of photography; others were nature interpreters. While the photographers would strive to reproduce the old photograph the interpreters would document and describe the similarities and changes that they recognized from the old photo, as well as compare their own findings to past field notes. To make it easier for future repeat photographers to document the changes, the team also recorded the location and orientation of the camera, and information about the camera settings. Webb (1996) estimates that repeating one landscape photo and interpreting the geography and vegetation of the area takes over two hours.

Qualitative analysis of a photograph allows for basic landscape characteristics to be determined, such as the type of land use, the geomorphic characteristics, as well as the existence of specific objects (Lillesand & Kiefer, 1994). Elliott and Baker (2004) used repeat photography to document the changes in the San Juan Mountains of Colorado over time. They were able to record visible changes in stand structure and vegetation type, as well as species invasions through photographic analysis. Qualitative analysis revealed that aspen had invaded established coniferous forests during the period in between photograph pairs. They used the qualitative information gained through their photo pair to assess the invasion patterns of aspen over the past several decades (Elliott and Baker, 2004).

In their study published in 2006, Zier and Baker discuss the substantial body of research that has been conducted concerning the shifting boundaries of ecological landscapes, particularly relating to the relationships between forest-grass and shrubland boundaries. Within western forests, there has been increasing awareness of the encroachment of forest onto grass/scrubland within the past century. This landscape change has been primarily attributed to the climatic changes that have occurred over the past 100 years. As well, fire suppression and the influences of grazing may have been key instruments dictating the vegetation distribution. Zier and Baker (2006) suggest that both human changes to land use patterns, as well as climatic fluctuations have resulted in an altered ecological landscape in the San Juan Mountains of Colorado.

Within northwestern Yunnan, The Nature Conservancy uses repeat photography to assess the ecological landscape changes that have occurred over the past 100 years. Since the beginning of their massive photo project, The Nature Conservancy has collected over

1000 historical photos from historical books and journals, the archives of the National Geographic Society and the Royal Geographical Society, as well as many other institutions in both the United States and Europe. The historical photos were taken from 1899 to 1949 by Western explorers, including geographers, botanists, missionaries, ethnographers and tourists, who traveled through the area. From 2001 to 2005, the Nature Conservancy duplicated 413 of these historical photographs that form a database of qualitative landscape information about the area as a quick method of informing conservation policy and establishing a base-line of information for future research (Moseley, 2006).

Moseley (2006) uses visual indicators, such as vegetation communities, tree-lines, erosion, burning and grazing, as well as infrastructure to determine the significance of the land use changes that have occurred in northwestern Yunnan over the past 100 years. Through his detailed qualitative assessment, Moseley (2006) concludes that analysis of the photo pairs taken by the Nature Conservancy does "not support the widespread assumptions made regarding Yunnan's environmental degradation" (p. 218). He goes on to say that "the causes of glacier retreat on the peaks and the presence of arid shrublands in the canyons have been blamed on the wrong sources" (p. 218). He argues for a reassessment of the severity of the possible threats to environmental degradation in northwestern Yunnan, particularly as it pertains to the traditional minority groups who have been living on this landscape for centuries.

Quantifying the ecological changes over time using photographs has proven more challenging than a presence/absence assessment. Baker and Moseley (2007) quantified the changes that were seen between their photo pairs by physically traversing the slopes of Baima Snow Mountain and Mount Khawa-Karpo in northwestern Yunnan. While in the field, one researcher would locate the photo point where the photo pairs were taken and guide the second to the location of any land use boundaries, such as the tree-line or the edge of glaciers. They were able to GPS the locations and quantify the changes. Throughout their research, Baker and Moseley concluded that both local anthropogenic disturbances caused by changing land use practices and policies, as well as global climate warming, were responsible for altering the tree-line and vegetation dynamics of the alpine environment. Because of policy changes limiting fire and grazing in alpine meadows, woodlands are encroaching. This is of particular significance to biodiversity conservation, as alpine meadows are populated by a significant number of endangered and endemic species (Ma *et al.,* 2007).

Using repeat photography as a research tool for evaluating ecological landscape changes is not without limitations. A single terrestrial photograph only represents a small area of the larger landscape. It is difficult to justify making generalizations about the environmental conditions of an entire landscape based on a few representative photographs. Using several 'sample' photographs allows for a more general look at the broader area (Hutchinson *et al.*, 2000). Also, landscape changes are difficult to perceive and quantify. Stochastic events such as a fire or an insect infestation will significantly disrupt the landscape of one area, while the vegetation at adjacent sites remains unchanged. As well, any stochastic environmental events occurring during the time interval between photographs will not be documented through repeat photography if the landscape has recovered. And, if the landscape has experienced a stochastic environmental event and has not yet recovered, although the significant impact on the landscape remains, the cause of the change may not be realized through a repeat photography study.

One of the realities of repeat photography is that those retaking photographs are usually constrained by the original photo locations. Commonly, the historical photographs used for repeat photography studies were not taken by researchers with the intention of duplicating the photo. They were frequently taken by explorers, tourists, and homesteaders who provided nonrandom presentations of the landscape (Hutchinson *et al.*, 2000). There is little data available on the land use history of the photo sites to make detailed comparisons. Also, the original landscape photographs used for repeat photography studies may have been artistically altered. The original photographer may have altered the photographed area, or selected the photo point for a specific reason, unknown to the researcher performing the study. For example, some photographers will intentionally fell trees for a better view (Pickard, 2002).

Photo pairs can also be mismatched. Researchers retaking historical photographs should replicate the time of day, season, weather conditions, and exact photo point as closely as possible (Pickard, 2002). Seasonal changes between photo pairs can be used to exaggerate or minimize landscape changes. Any discrepancies between photos of the same landscape should be recorded and taken into account during analysis.

With particular reference to documenting land use changes through repeat photography, it is important to note that although changes in forest cover, as well as forest density, can be adequately assessed using rephotography, the health of the forest ecosystem is extremely difficult to measure using landscape photographs. For example, many villagers will practice selective tree felling for fuel wood and building material. This anthropogenic disturbance to the forest ecosystem can cause changes to both forest structure and levels of biodiversity, but cannot be properly measured through landscape photos (Moseley, 2006). There are significant limitations to assessing ecosystem health through repeat photography.

Despite its drawbacks, repeat photography is another approach that can be used to uncover unknown knowledge about changing landscapes. A substantial set of photographs that are unbiased and represent the landscape well will improve the weaknesses of the methodology. Photographs capture a 'sense of place' (Eyles, 1985) and allow the collection of the subjective and the experiential to accompany objective characteristics. Photographs communicate a story, comprised of many different parts. Repeat photography reveals information about various characteristics of the environment, from vegetation to land use, to culture, in an incorporated whole. Repeat photography can provide a comprehensive picture of an area and together with the information gained through other methodologies; repeat photography can be used to formulate a body of knowledge that will better inform conservation policy.

2.7 Land Use and Cover Change in Northwestern Yunnan

Land use and land cover change research is an important tool for assessing ecosystem dynamics because both land use and land cover affect ecosystem functions, such as nutrient cycling, water dynamics, soil structure and erosion patterns (Ediger & Chen, 2006). These factors have a considerable influence on ecosystem health (Ediger & Chen, 2006). Land use and cover changes are affected by geomorphic, socioeconomic, and political powers; each of these factors has played a significant role in changing the ecological landscape of northwestern Yunnan over the past century (Melick *et al.*, 2006b).

The high-altitude environment of northwestern Yunnan has been influenced by anthropogenic disturbance at least since the first Tibetan herders immigrated to the area over 2000 years ago, if not earlier (Baker & Moseley, 2007). Since that time, fire and grazing regimes have influenced the altitudinal limits of vegetation distribution in this area.

Baker and Moseley (2007), who conducted a repeat photography study in the Tibetan region of Yunnan Province, acknowledge the continued presence of anthropogenic activity through the past century, as ecological changes caused by both fire and grazing are noted in their photo pairs.

Willson (2006) used satellite imagery from 1981 until present to assess the land use changes that have occurred in Xiaozhongdian Township, northwestern Yunnan. The principal land use change noted since 1981 was the deterioration of forested area and the conversion of these areas to shrublands. Rangeland and grassland area also declined and were replaced by shrublands. Willson attributes the loss of forest cover to the commercial logging industry before the logging ban began in 1998. He also suggests a significant insect infestation, which may have caused further loss of forest cover (Willson, 2006). Willson notes a significant decline in forests and their conversion to shrublands. Over the time period from 1981 to 1999, Willson saw a 37% decrease in cultivated lands. A significant portion of this area was converted into grassland for livestock management. This land use timeline corresponds well to China's implementation of the Household Responsibility System where the farmers were given control of their agricultural and grazing lands. Rangeland areas were also reverted to shrublands over the study period. Willson suggests that this is due to many factors, including subsistence strategies, smaller family size, and government regulations limiting rangeland use and prohibiting controlled burning. These factors have caused the encroachment of many woody species, such as the inedible *Rhododendron* species, into areas previously occupied by rangelands (Willson, 2006; Wilkes, 2006). Overall, Willson attributes the land use and land cover changes that have occurred since 1981 to local anthropogenic factors, from farming practices to government regulations.

Ediger and Chen (2006) study the changes to the ecological landscape in Yangliu Township, Yunnan Province using Landsat images from 1989 and 2001. They determine that the landscape changed significantly over this time period. The agricultural land area declined over 25% and grain production was significantly reduced. The effect of this land use transition on the household economy is evident, as farmers have seen both a decline in food resources and economic opportunities. The agricultural land was converted into land classified as mixed grassland or shrubland; however, the trees that were planted in this area in the late 1990s were too young to classify the land as forest. Ediger and Huafang (2006) notice a transition from farmland to forested lands; however, they also note that the afforestation efforts have occurred primarily on the less severe, more agriculturally valuable slopes, contrary to that recommended in national conservation policy goals. Farmers are converting valuable agricultural land to forested area because of the subsidies promised by the Chinese government.

Moseley (2006) uses repeat photography to assess the land use changes that have occurred in northwestern Yunnan over the past century. He claims that local people have been falsely accused for much of the landscape deterioration that has occurred in the past 100 years. Contrary to popular thought, Moseley claims that forest cover has changed little over the past century due to local anthropogenic use. He explains that in all of the landscape photos depicting scenes managed by local groups, forests have sustained both cover area and tree density. In some places, it has even increased. Moseley (2006) does note that forest fires have played a role in the ecological landscape changes that have occurred over the past century. He also suggests that there has been significant cropland abandonment in forest regions during the past century. He notices that villagers in some areas are continuously using forests, but deforestation for local fuel and building materials has not had a significant effect on the forest cover area, or tree density.

Like many of the other studies, Moseley (2006) found that the clearing of native vegetation for agricultural crops appears to have declined over the past century despite population increase. Abandoned croplands have been converted to shrubland or forests. Moseley suggests that previous statements declaring that there has been drastic forest clearing in northwestern Yunnan over the past 50 years have over dramatized the threats to biodiversity in the area, as forest clearing for agricultural lands has been happening for centuries.

For instance, his photo comparisons along the Yangtze and Mekong rivers reveal that arid shrublands are a continued dominant ecosystem type on the mountainous terrain (Moseley, 2006). Many policy makers in southwestern China believe that this ecological landscape feature has been caused by the severe deforestation of mountain slopes; however, the low precipitation levels in these regions are caused by the rain shadows created by adjacent mountain ranges. If they had read the work done by Frank Kingdon-Ward they would have realized this. Moseley asserts that this error has resulted in reforestation programs in areas that, ecologically, cannot support trees (2006).

As well as more localized anthropogenic land use, global climate change has been recognized as a major influence of alpine and upper treeline vegetation dynamics. Moseley (2006) asserts that there are also ecological impacts that indicate a warming climate. Rephotography has indicated an ascending alpine timberline and an encroachment of shrub cover in alpine meadows indicates the climate change has been the primary player altering the high-altitude landscape.

Temperature has been identified as being the primary factor impacting vegetation at high altitude. Moseley notes the significance of the retreating glaciers in northwestern Yunnan: The loss of snow and ice from high mountain regions has been considered a prime indicator of a warming climate (Moseley, 2006). In fact, although the means are uncertain, northwestern Yunnan appears to be more greatly affected by climate changes than the rest of China. Annual temperatures have averaged a 0.06°C increase per year since 1980, twice the national average (Baker & Moseley, 2007).

Precipitation levels are also a significant feature directing vegetation distribution in high-altitude environments. The treeline species composition is greatly influenced by annual levels of precipitation. *Larix* species respond positively to warmer, more arid environments, whereas *Abies* species and *Picea* species, the other two dominant genera present at high altitudes in northwestern Yunnan, tend to thrive in cooler, wetter conditions (Liu *et al.,* 2002). Using repeat photography, Baker and Moseley (2007) suggest that the alpine environment in northwestern Yunnan has become warmer over the past century, as the glaciers of the region are experiencing accelerated recession. They also propose a drier environment, as the *Abies* forest has not advanced higher on Mount Khawa Karpo, despite the retreating Mingyong Glacier, but the woody scrub species, such as *Rhododendron* species, and the *Larix* woodlands are invading the alpine tundra as the glacier recedes on Baima Snow Mountain (Baker & Moseley, 2007).

Two extremes of anthropogenic disturbance, global climatic changes resulting in a warming climate and the local land use policies and practices employed, seem to be the primary players responsible for affecting the high altitude environments of northwestern Yunnan.

2.8 The Arrival of Westerners to Northwestern Yunnan – The Plant Hunters

China's unique floral diversity first became evident to Europeans during the late nineteenth century. This revelation is attributed to the work of three botanists who provided a continuous supply of unique herbarium specimens from China's uncharted interior to Europe for the advancement of botanical knowledge. Access to in-land China was improved in the 1860s, following treaties imposed after the second Opium War that allowed for greater foreign access. French missionaries Jean Pierre Armand David (1826-1900) and Jean Marie Delavay (1839-95) sent dried plant collections back to the Musée d'Histoire Naturelle in Paris (Musgrave *et al.*, 1999). Augustine Henry (1857-1930), an amateur botanist, collected plants specimens as a hobby and sent them back to the Kew Herbarium in London, England (Musgrave *et al.*, 1999). These unique and diverse specimens sparked interest among plant collectors and botanists worldwide.

After this, Yunnan became a haven for commercial plant collection during the early 20th century. Botanical explorers supplied seeds to the growing horticultural market that existed in Europe during that period. Among the leading botanical explorers were Ernest Wilson, George Forrest, Frank Kingdon-Ward, and Heinrich Handel-Mazzetti. These men did not only contribute to the field of botany and introduce new species into our gardens, they also documented the landscape and ecology through field notes, journals and photographs that provide detailed accounts of the ecological landscape of the area a century ago (Wilson, 1927).

George Forrest (1873-1932), a devoted outdoorsman, spent twenty-eight years exploring and collecting flora from western China (Musgrave *et al.*, 1999). Unfortunately, his expeditions were never formally recorded. An early and unexpected death prevented Forrest from thoroughly documenting his botanical journeys, a task that he had reserved for his retirement. Only fragmented accounts of his expeditions are available to interested readers. During his expeditions, he discovered several new species of alpine plants, including *Gentiana sino-ornata, Primula bulleyana*, and *Rhododendron* species growing in alpine meadows and scrub at high altitudes, such as *R. haematodes* and *R. griersonianum* (Musgrave *et al.,* 1999). His work that is published offers pieces of the ecological landscape of northwestern Yunnan in the early 20th century.

The international recognition of the significant horticultural value of Yunnan Province is primarily attributed to the publications of Frank Kingdon-Ward (1885-1958). Throughout his career, Kingdon-Ward wrote a series of books documenting his travels and adventures as a professional plant collector in the Asian wilderness. He also frequently published articles in *The Geographical Journal,* such as "From the Yangtze to the Irrawaddy" (1923) and "The Snow Mountains of Yunnan" (1924), each documenting his botanical and geographic findings and landscape photographs. Kingdon-Ward is celebrated today as a renowned botanist, horticulturalist, and geographer. Some of his most well-known plant introductions are *Primula burmanica, Rhododendron wardii*, and *Meconopsis betonicifolia*, after which, his book, *The Land of the Blue Poppy*, is named (Musgrave *et al*., 1998). His detailed maps and photo documentation of the high-altitude environments of northwest Yunnan offer significant information about the ecological landscape of the area a century ago.

General H.R. Davies also contributed significantly to the body of knowledge through his general documentation of his experiences in Yunnan Province. He and Kingdon-Ward would frequently critique and validate each other's findings. This is evident in the correspondence seen in the archives of *The Geographical Journal*, such as

"Exploration in Western China: Discussion" (1903) and "The Valleys of Kham: Discussion" (1920).

Generally, very little is known about the explorations of the Austrian botanist Heinrich Handel-Mazzetti. He collected plants in Yunnan Province during the uncertain period of World War I. He published an account of his experiences and findings in 1927 entitled, *Naturbilder aus Südwest China*, which has since been translated into English (Winstanley, 1996). In his book, Handel-Mazzetti meticulously documents the flora and provides a detailed account of the variety of species witnessed in certain areas. Unlike many other plant explorers, Handel-Mazzetti did not only focus on the most visually appealing plants, but thoroughly documented all floral richness (Wilson, 1927). His field notes allow for detailed ecosystem analysis and comparisons.

Joseph Rock, a geographer and ethnologist, is another famous botanical explorer who traveled to northwestern Yunnan in the early 1920s. He is known for both his fearless personality and eccentricities. He was willing to travel far into the wilderness, as long as he could bring along his phonograph, silver flatware, and a rubber bathtub (Ganong, 2008). Born in Austria, Rock immigrated to the United States in his early twenties and became an expert on Hawaiian botany, teaching courses at the University of Hawaii. He traveled to Burma, Malaysia, and India in search of unique botanical species before traveling to northwestern Yunnan.

Rock lived in Yuhu (Nguluko) village, a small community just outside of Lijiang, Yunnan Province, between 1922 and 1949. He became a leading expert on not only the local botany of the area, but also the local Naxi culture. The United States Department of Agriculture and Harvard University were the chief sponsors of his trips to northwestern Yunnan. *National Geographic* magazine also sponsored several of Rock's trips to northwestern Yunnan and he became an official correspondent of the magazine, publishing nine articles reflecting the geography and ethnography of the region from 1924 to 1935 (Ganong, 2008). Articles included "Through the Great River Trenches of Asia: National Geographic Society Explorer Follows the Yangtze, Mekong, and Salwin Through Mighty Gorges" (1926) and "Seeking the Mountains of Mystery: An Expedition on the China-Tibet Frontier to the Unexplored Amnyi Machen Range, One of Whole Peaks Rivals Everest" (1930). Rock also sent over 60 000 specimens to the Smithsonian Institute in Washington, D.C. and collected seeds for the Department of Agriculture. Rock was also a devoted photographer and thoroughly documented the landscape of northwestern Yunnan with high-quality photographs. The landscape photographs taken by Joseph Rock on his expedition to northwestern Yunnan in 1923 provide the photographic information used for this study. The published books, journal articles, and personal writings of the other plant hunters, botanists and explorers offer the literary detail that cannot be interpreted through landscape photographs. These resources provide a readily available source of historical landscape information to assess past ecological land use changes.

2.9 Summary

Yunnan is an area of unprecedented biological and cultural diversity; however, due to past overexploitation of natural resources due to a lack of environmental knowledge, the ecosystem health of the region is under threat. Recent policy reforms encouraging environmental preservation have been created based on little evidence of past ecological landscapes. There is some evidence that environmental policy has misidentified some of the drivers of the land use changes and biodiversity loss that have occurred in northwestern Yunnan over the past century. Although some studies have been conducted assessing ecological landscape changes in the area, much more research has to be done to better inform conservation policy. Repeat photography has been identified as a useful tool for assessing ecological landscape changes over time. Fortunately, historical photographs are available from the early plant hunters, geographers, and botanists who traveled to Yunnan in the early twentieth century. Their historical photographs, as well as detailed field notes, create a window into landscapes past.

While Chapter 2 provided background information about the biogeography of the landscape and the contemporary political issues concerning land use change, it also introduced a method of assessing ecological landscape changes in northwestern Yunnan over the past 100 years. Chapter 3 discusses the specific methods that I used to perform my rephotography study using the historical photographs taken by Joseph Rock in 1923. I also discuss the irreplaceable experience of conducting fieldwork in northwestern Yunnan.

3.0 Methodologies: Fieldwork and Analysis

3.1 Introduction

Chapter 2 introduced the process of repeat photography as a useful method for assessing ecological landscape changes over time. This chapter discusses my rationale for selecting the historical photographs taken by Joseph Rock of the upper Yangtze River Basin to use as the basis for my repeat photography study. This chapter also presents a detailed account of my fieldwork methodology for repeating the historical photographs, as well as recording the local vegetation communities and land use patterns. I also provide a narrative of the challenges that I faced performing international fieldwork in northwestern Yunnan. Finally, I talk about my methods of analysis, including the qualitative assessment of the land use changes and quantitative assessment using photo grid analysis.

3.2 The Study Area

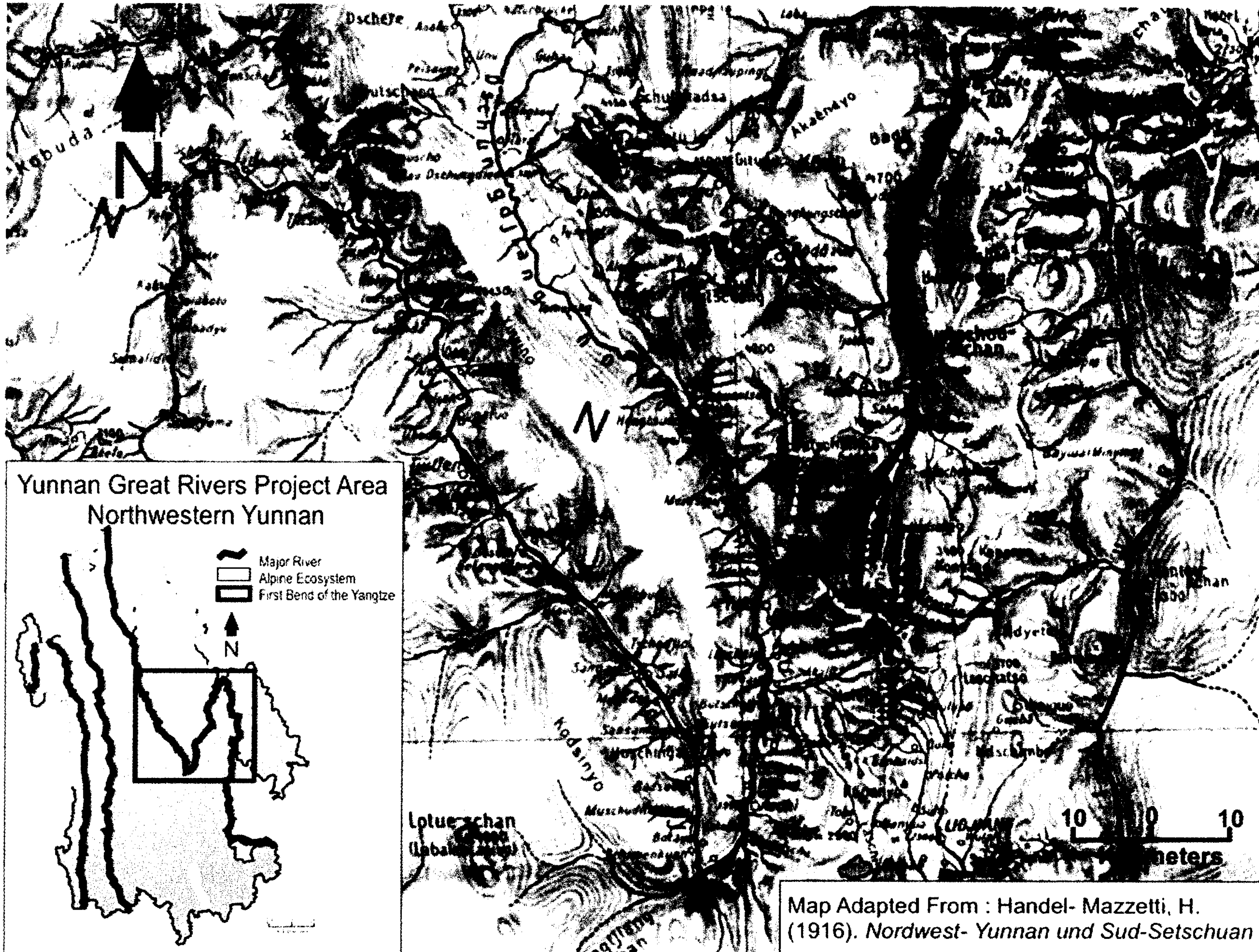
This study was conducted along the upper reaches of the Yangtze (Jingsha) River (refer to **Figure 3.1** on page 43) from the Li-chiang - Wei-hsi border (27°32'39.23" N, 99°33'22.03" E), around the First Bend, and through Tiger Leaping Gorge (27°17'46.86"N, 100°1326.06" E). The Yangtze River originates in the high mountain regions of the Tibetan Plateau and descends from that high altitude environment flowing south through northwestern Yunnan before turning east, carving through mountain ranges and twisting through flat lowlands until reaching the ocean at Shanghai (TNC, 2008). Winding a path of 6397 km, the Yangtze River travels a more latitudinal than longitudinal path once it leaves northwestern Yunnan and makes its way east across China. The Yangtze River is the longest river in China and the third largest river basin in the world. Its basin encompasses an area greater than 1.8 million km^2 and it provides water to the 400 million people who live within its watershed (Jiang *et al.,* 2008).

Ecological landscape changes that occur in the Yangtze River basin in northwestern Yunnan are of primary global conservation concern (Fullen *et al.,* 1999). Within northwestern Yunnan, the Yangtze River traverses tectonically active and unstable mountainous regions. In addition, the Yangtze River basin within this region is an area of intense terraced agricultural production (Fullen *et al.,* 1999). This area has been relied on for generations as a source of water, fish, and irrigation for agriculture. In recent years, the Yangtze River has become a means of producing electricity for China's rapidly growing economy. Lately, northwestern Yunnan has become a haven for tourism and there has been a significant amount of literature published about the environmental and socioeconomic impacts of these changes (Anderson *et al.*, 2005; Buntaine *et al.*, 2007).

3.3 The Selection of Historical Photographs

Commonly, a repeat photography study reveals itself when historical photographs expose evident landscape changes (Pickard, 2002). Dr. Will Wilson came across historical photographs from northwestern Yunnan that did just that. These historical photos were taken by the plant hunters, geographers, and botanists who explored the northwestern Yunnan in the early twentieth century. After that, Dr. Wilson began actively seeking historical photos of northwestern Yunnan for a potential research project. He compiled over 200 high-resolution historical photographs into a database. The sources of these photographs were mostly published journal articles and books. The photos ranged from portraits, to cultural festivities, to architecture, to vegetation and ecological landscapes.

Figure 3.1 A map of the study area: The Yangtze (Jingsha) River from the Li-chiang - Wei-hsi border (27°32'39.23" N, 99°33'22.03" E), around the First Bend, and through Tiger Leaping Gorge (27°17'46.86"N, 100°1326.06" E).



I used his database of historical photos as the foundation for my repeat photography project.

The selection of the historical photographs I used in my study was conducted with similar methodology to that performed by Zier and Baker when they used historical photographs to assess the landscape changes that have occurred in the San Juan Mountains of Colorado (2006). The first step was to collect as many old photographs as I could. I gathered landscape photographs from journal articles to add to Dr. Wilson's collection. From the pool of available photographs, I chose to consider only those photos that adequately depicted the ecological landscape of an area. Of these, I selected only the photos that display a high quality image and are easily located in the field, meaning that the location where the photograph was taken is described well in field notes or that the photo contains geomorphic landscape features that are easily recognized. I noted that Joseph Rock produced high-quality images and provided a thorough documentation of the historical landscape in this area through photographs. Based on the photos that met my requirements, I selected the study area of the Yangtze River Valley surrounding the First Bend of the Yangtze and downstream through Tiger Leaping Gorge because, in addition to the high-quality historical images, there is a significant amount of literature written by other Western explorers, including Frank Kingdon-Ward and Heinrich Handel-Mazzetti, that provides a detailed spatial record of the local land use and vegetation communities present in this area a century ago. I used the writings of Kingdon-Ward, Handel-Mazzetti, and Rock to reconstruct the vegetation communities that existed within the first bend of the Yangtze over a century ago.

In 1998, the Chinese government asked the Nature Conservancy to help them perform an assessment of the ecological landscape of northwestern Yunnan. Beginning in

2002, the Yunnan Great Rivers Project was designed with the goal of achieving sound conservation policy: effectively preserving ecosystem health and biodiversity while ensuring sustainable livelihoods for the local population. Because of the lack of baseline ecological research in the area, the Nature Conservancy started a study using historical repeat photography to better assess ecosystem dynamics, patterns of disturbance and possible threats (Lassoie & Moseley, 2006).

Nature Conservancy has accumulated historical photographs taken by western explorers in northwestern Yunnan (Moseley & Tang, 2006). Over 400 of the historic photo locations were identified and the photos were repeated. Bob Moseley of the Nature Conservancy granted me access to the photo pairs that the Nature Conservancy took of the Yangtze River Basin in my study area. These photographs increase the landscape area addressed in the analysis of this study. Through this study, I am able to conduct an ecological analysis of the landscape change within the First Bend of the Yangtze that is of greater detail than that previously conducted by The Nature Conservancy.

In the end, I rephotographed 10 landscapes that were originally photographed by Joseph Rock. I also included 12 additional photo sets that were done for the Yunnan Great Rivers' Project by Robert Moseley. In total, I considered 22 photo sets of the First Bend of the Yangtze River for this study.

3.4 Equipment Selection for Landscape Photography

I did a significant amount of research about what type of equipment should be used for the fieldwork of this study. Quality photographic monitoring equipment is essential for documenting landscape changes in rural environments. The equipment used during international fieldwork has to be both hardwearing and dependable to withstand varying weather conditions, light weight and compact for traveling purposes, and be able store thousands of images. Because of the location of the study area, it was also important that the equipment be capable of working for several days without the batteries needing to be recharged.

Measuring landscape change requires equipment that can provide exceptional resolution and colour depiction. Hall (2002b) recommends single lens reflex (SLR) cameras because their 'view-through-the-lens' system improves composition and allows for fine-tuning during exposure. I conducted my fieldwork using two film cameras, a Nikon N90 and a Nikon N80, which accept interchangeable lenses. Each of the cameras met Hall's (2002b) requirements for a fieldwork camera. For repeat photography, it is important to document the brand, type of film and ISO reading that will be used. Also, taking pictures in both colour, and black and white, is recommended because, while colour images may supply more information, they will fade over time, and black and white photos will not fade (Hall, 2002b). I chose to take film photographs using Kodak Professional T-Max 100 black and white film and colour slides using Fujichrome Provia 100 F Daylight slide film.

Regarding digital cameras, Hall (2002b) suggests that a camera of 2.4 megapixel resolution or higher is necessary for photo analysis. For my fieldwork, I used the Nikon D40X, a professional, high resolution, digital single lens reflex camera. This model is ideal for fieldwork because, although it is extremely small and compact, it is capable of accepting interchangeable lenses and there are many options incorporated in the camera body for attaining, adjusting, and storing photo images. This camera has a resolution of over 10 megapixels, far more than Hall (2002b) recommends. Because of the detail that needed to be present in the landscape photos used for analysis, I adjusted the settings to maximize the image quality. More detailed images require a longer exposure period;

therefore, I used a sturdy tripod to steady the camera while the images were being exposed. The images were stored on 4 GB memory cards until they could be transferred to a computer and backed up on USB storage keys in Lijiang, my base during fieldwork.

Lens quality is also an important variable for this type of research. Lassoie and Moseley (2006) tested different zoom lenses during their rephotography study in northwestern Yunnan and determined that for a digital camera, the optimal focal length for landscape photos ranges from 18 to 180mm. I brought two digital lenses to northwestern Yunnan for this study; a Nikkor 18 to 55mm digital lens[5] and a Nikkor 55-200mm digital lens. A Nikkor fixed 28mm film lens and an AF Nikkor 24-50mm film lens were brought for the film cameras. The film lenses fit both camera bodies.

Many researchers conducting rephotography studies cite the problem of temporary storage (Lassoie and Moseley, 2006). I carried two 4 GB memory cards for my digital camera, as well as several additional rolls of film. To ensure that temporary storage was not an issue, I scheduled out trips for periods of no more than four days. Once back in Lijiang, I transferred the digital photos to a laptop and backed them up on USB storage keys.

The rechargeable battery in the Nikon D40x camera proved to be long lasting and could go for periods of over a week without needing to be recharged when taking over 100 photographs per day. I rarely used the flash for photographs and limited my use of the

[5] Many of the digital SLRs have sensors that are smaller than the usable area on a 35mm film. The digital sensor diagonal is 1.5Xs smaller than that on a film camera. As a result, the digital sensor captures only the middle portion of the information projected by the lens; therefore, the photographer will end up with a cropped field of view. On some cameras, the lenses are interchangeable between digital and film; however, the photographer must always be aware of the reduction of the photo area when using a digital camera. This is especially true for repeat photography studies.

LCD screen to ensure that the batteries lasted during out trips. The film cameras were less reliable, needing a substantial supply of replacement batteries.

3.5 Fieldwork in Northwestern Yunnan

Geography is undoubtedly a discipline founded in the importance of fieldwork. As interpreters of the landscape, geographers exhibit an interest about the world that lures us into the field. The process of landscape interpretation in the field is both overwhelming and lengthy. It is important for a researcher conducting fieldwork to stay on track, focused, and not allow the complexity of a field experience to influence the task at hand. Herbert *et al.* (2005) discuss fieldwork as a "compelling endeavor"; however, they also acknowledge fieldwork as a "rigorous, demanding and often frustrating experience" (p. 227). My fieldwork expedition to northwestern Yunnan was no exception.

Field research took place in northwestern Yunnan from early May 2008 to late June 2008; a period of almost 2 months. For the first three weeks in northwestern Yunnan, I assisted in a geography field school. I became familiar with my study area, and made some initial identification of photo sites. The time also allowed me to create local contacts to help with my fieldwork. When the field school concluded, I, along with my undergraduate field assistant Laura Profota, stayed in Lijiang, Yunnan Province to conduct my field research. Some further details of this research are provided later in this chapter.

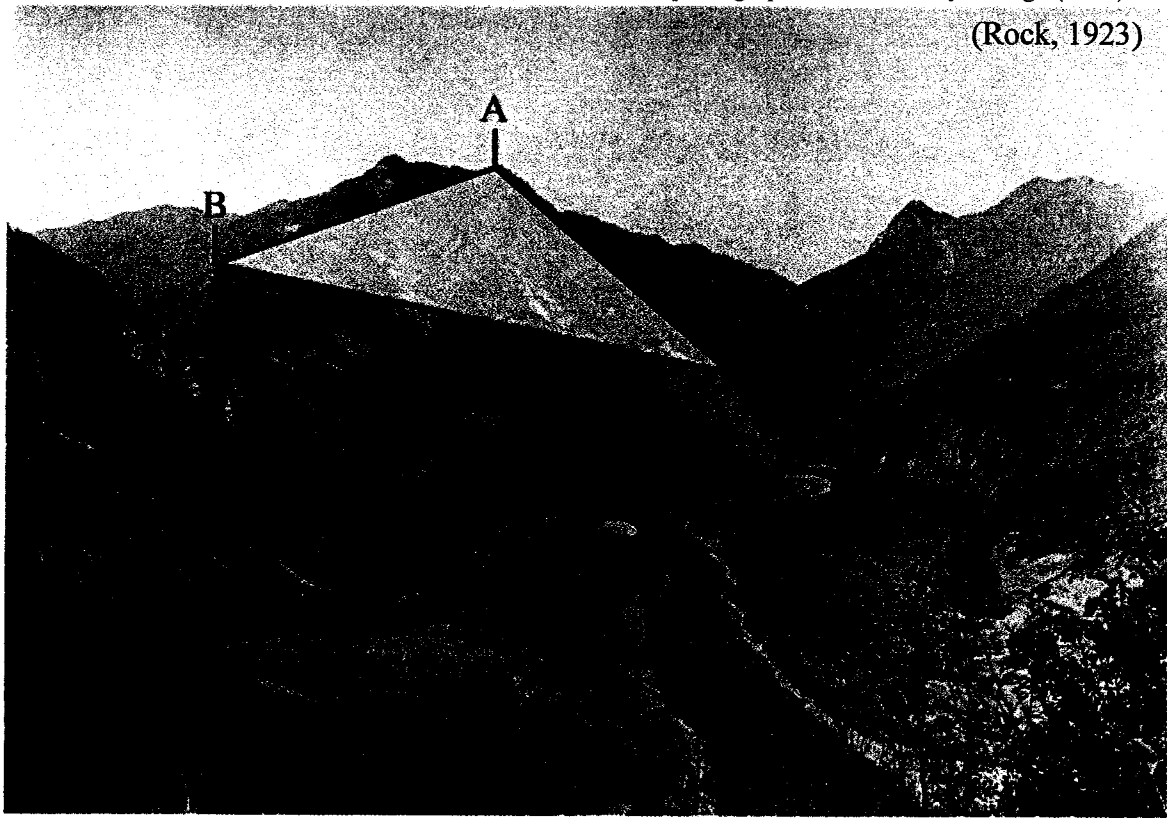
3.5.1 Repeat Photography Fieldwork

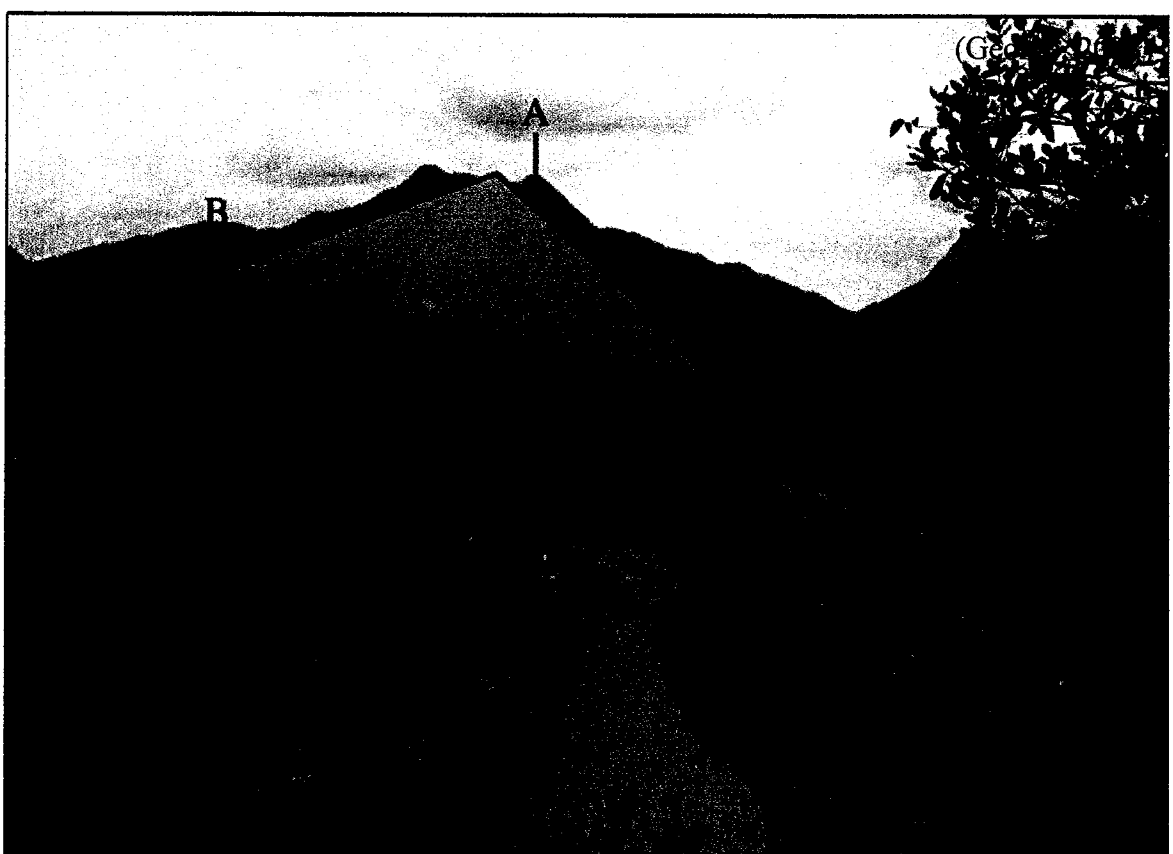
The locations from which the original photographs were taken were not physically marked, but detailed in the description of each photo. In order to find the approximate photo point, I used the triangulation procedure explained by Hall (2002a). First, orientation points were established. I used geomorphic landscape features as my orientation points because they do not change significantly over time. **Figure 3.2** (p. 50) shows the orientation points and triangulation of Photo Set #3. The triangle was drawn on the hard copy of the historic photo that I took into the field for comparison. Point A marks the centerline of the triangulation and Point B and Point C are distinct, unchanging landscape features that are towards the sides of the photo and are used to triangulate the location of the original camera point. I used the original photograph with the triangle drawn on to locate the photopoint by eye. After digitally retaking the photograph, I compared it to the original using the LCD screen. Hall (2002a) suggests that after the triangulation is complete and the original photograph is centered, the photographer should move forward and backwards until the angles of each marked point is comparable to the original photograph.

Hall (2002a) explains the triangulation procedure very well in theory; however, the triangulation of a photo point in practice is significantly different. The top image in **Figure 3.2** (pg. 50) is the photo that Joseph Rock took in 1923. Below it is the photo that I took in 2008 using the triangulation procedure. In the 2008 image, the camera was to the right and at a somewhat lower elevation that the original photo point. I knew that this was the case when I retook the photograph, but the overhead forest canopy prevented a more accurate replication of the photograph. This photo was taken from a clearing on the side of a forest-covered mountain to adequately show the landscape changes.

While at each photo point, a significant amount of other information was collected. **Table 3.1** (p. 51) shows the photo information that was recorded during my fieldwork expedition at each photo point, as well as their definitions. Laura and I recorded the latitude, longitude, altitude, time, and date using the Garmin GPSMAP 72 with three meter

Figure 3.2 Repeat photography: The orientation points and triangulation procedure shown on Photo Set #3. The top photograph was taken by Rock (1923). The bottom photograph was retaken by George (2008).





horizontal accuracy, as well as an altimeter, the Kestrel 4000, to measure the altitude[6]. We also used a compass to record the orientation of the photo. As well, Laura and I documented the landscape characteristics, local dominant vegetation, and any noteworthy species by taking additional photographs and recording field notes. I also took the time to note any indications of disturbance to the natural environment, as these factors are important for conservation targets. Problems with successfully locating the original photo point, such as vegetation cover, infrastructural development, or time restrictions, were recorded along with the weather conditions. All of these additional resources can be used to enhance the understanding of landscape changes, as well as allow for easier identification of the photo point in the future.

Table 3.1 Cataloging photo information

Photo Information	Explanation
Location	**Description of the location and directions to photo point**
GPS	Latitude, Longitude, Altitude,
Orientation	Direction faced to retake photo (compass bearing)
County	Political location of photo point
Landscape Characteristics	
Ecoregions	Vegetation communities present in the photo
Land Cover	Dominant Vegetation
Land Use	Anthropogenic alterations (logging, agriculture, grazing)
Infra-structure	Buildings, bridges, roads, power lines, etc.
Disturbance	Soil erosion, forest clearing, mining
Conditions	
Date and Time	A record of the date and time that the photo was retaken
Air Quality	A record of the weather conditions and light quality
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location

[6] Historically, barometers were used to determine altitude. Today, GPS units are able to measure altitude, but many are not very accurate (within 30m). I chose to use the Kestrel 4000 wind/altimeter/weather tracker to determine the altitude of each photo point as it measures altitude through barometric pressure. The datum used in the Garmin was WGS-84.

3.5.2 Vegetation Sampling

While conducting my rephotography fieldwork, I also recorded the botanical species present through photo documentation and field notes. I focused on documenting the dominant vegetation types, as well as notable indicator species[7]. For each species photographed, I documented the flower, stem or trunk, leaves, and entire plant with a scale provided in each photograph. As well, GPS points were taken regularly to note the altitude and location were the noted species were present.

While in the field, I relied on several texts to identify plants. They include: Polunin and Stainton (1987), Stainton (1988), Polunin and Stainton (1984), and Wu and Raven (1999). Using these texts, plant species were identified and the photographs of each species were catalogued and numbered, and the location of each species was noted. While the field guides written by Polunin and Stainton were useful for the high-altitude flowers found during my fieldwork, The Flora of China provided a detailed catalogue of the floral species present in all of China. During my fieldwork, I would often spend my evenings identifying the different species that I had encountered during that day. Landscape photographs were taken frequently to document the forest canopy in different areas. The species in each landscape photograph were identified, therefore determining the suggested vegetation type (in **Table 2.1**, page 15). Any species that could not be identified to a certainty in the field was identified using the photographs when I got back to the lab.

[7] An indicator species is defined by Dufrene and Legendre (1997) as "the most characteristic species of each group, found mostly in a single group of the typology and present in the majority of the sites belonging to that group."

3.5.3 Fieldwork Challenges

Conducting international fieldwork is not without challenges. It requires a significant amount of preparation that does not have to be done for local field research. Passports and visas need to be acquired, vaccinations need to be received, plane tickets need to be purchased, and equipment has to be bought. Any international traveler should thoroughly research their area of interest. It is important to look into the types of accommodations available, the transportation systems, and the costs. The cost of living in Yunnan Province is significantly lower than in Canada. Laura and I were able to get a comfortable room in a guesthouse for less than ten Canadian dollars per night. The significant cost for this research project was the plane tickets. Another issue to look into before international travel is personal risk. Yunnan Province is an area of high tectonic activity. We were in northwestern Yunnan during the Sichuan Earthquake[8]. Luckily, we only felt the tremors slightly, but this is always an issue to be aware of. The crime rates in China are very low in comparison to the rest of the world, making it not really an issue; however, being careful about our money, credit cards and passports was always important. Also, many people have trouble adjusting to international foods. Although I didn't feel the effects of this, many people who traveled with me on this trip were constantly sick because of the change in diet. It is important to travel with medications that are able to combat the effects of travel. It is essential for an international traveler to be prepared, especially with the added stresses of fieldwork.

Conducting fieldwork in a rural, mountainous setting introduces many obstacles. Having never been to an area as high in altitude, I was warned that I should stay active in Canada to combat the effects of altitude sickness. Hiking in the mountains at high altitude

[8] The Sichuan Earthquake occurred on May 12, 2008.

is extremely difficult for a person who is not acclimated to the conditions. We needed to bring a lot of water and snack foods to ensure that we didn't get dehydrated and to keep our energy levels high. It was especially difficult trekking through the mountains with all of the equipment required for my rephotography research. Originally, I naively hoped that I would be able to take along a laptop to conduct the preliminary photo analysis in the field. After spending a significant portion of the first month in northwestern Yunnan hiking the rugged topography, I realized that the difficulty of the trails, the unpredictability of the weather, and the size and weight of the computer would be a significant obstacle for preliminary in-field photo analysis. These issues were compounded by the poor battery life of the computer. I decided, instead, to take along laminated copies of the original photos and maps to locate the photo point where the original image was taken. Hiking with my clothing, toiletries, food, water, photography equipment, plant field guides, and my field notebooks in the high-altitude mountainous regions in northwestern Yunnan was challenge enough.

The seasonal timing of my fieldwork overlapped with the summer monsoon season in southern Asia. This caused significant frustration, as my fieldwork demanded cloudless days in order to get a view of the high mountain ranges. Many of the days that I had planned for fieldwork we ended up being stranded in Lijiang because of bad weather. This caused additional stress because we were only in Lijiang for a set amount of time. I had to make sure that I had gathered enough information to complete my thesis before I left.

Cultural differences also came into play while I was conducting my field research. I wanted to retake photos taken by Joseph Rock in Saba Gorge, a valley a couple of kilometers north of Lijiang. I attempted to find a local guide to take me to the area, but no one would. I was told that the area was sacred and that I shouldn't try to hike there. I didn't want to upset anyone, so I didn't end up repeating that series of photographs. It is important to respect the wishes of the local people when conducting international fieldwork and acknowledge that your fieldwork may not always go according to plan because of cultural differences.

Also, China does not allow foreigners access to detailed geographical information. Initially, I had intended to create a digital elevation model (DEM) of my study area; however, a 1:50 000 topographic map is required to create a DEM that is detailed enough to produce an accurate depiction of the landscape. Chinese maps of this level of detail are extremely difficult to access by the international community. In the end, I had to come up with another method of photo analysis (refer to section **3.6.3** on p.63 for further detail).

Language barriers caused a significant amount of difficulty, both in personal communication with local people and in the availability of scholarly research conducted in northwestern Yunnan. Because I cannot speak Mandarin, it was difficult for me to communicate with the local people. Lily Zhang, our tour guide for the undergraduate field school and the manager of a local ecotourism company called The Lijiang Xintuo Ecotourism Company, was a great help to me during my fieldwork. She organized our transportation and guides for the areas that I was unfamiliar with, translated information, and was always available to us in case of emergency. Laura and I traveled with an English/Mandarin dictionary at all times, but Lily was needed constantly as a translator. We would even call her from our driver's phone to communicate what we wanted to say when she wasn't there in person. I owe her a debt of thanks for her patience. The problem of the language barrier in international fieldwork also arises when attempting to find current, applicable literature about landscape changes in northwestern Yunnan. A significant portion of the research that has been conducted in northwestern Yunnan is only available in Chinese. Although several abstracts were available in English, the body of the literature is in Mandarin. This made it challenging to do a full search of the literature; although, I found that many of the important papers had been printed in English. Language barriers are significant obstacles when conducting international fieldwork in countries that do not speak English.

The finality of international fieldwork can be intimidating. With locally conducted geographical fieldwork the option of returning to your research site to collect more data is always there. For me, traveling halfway around the world to collect additional information to solidify my findings was not realistic. It is important to know exactly what your research plan is before you leave for your field research. This ensures that you travel with the right equipment and resources. That being said, it is essential for a researcher conducting international field study to be adaptable in case something doesn't go according to plan. Designing tentative research methods that are dependent on the environment was a challenge, seeing as I had never been to the study area before, but going through what I was going to do and the possible challenges that I was going to encounter really helped me to make certain that I had brought all of the right tools and equipment to conduct my research. While I was in China, I ended up changing the area of my fieldwork because I wasn't aware that an area that I had planned to photograph was sacred. Luckily, I had scanned my vegetation keys, photographs, maps, and site narratives and put them on USB keys. While I was in Lijiang I went to a local printing store to print all of the additional information that I required. Traveling prepared with a 'Plan B' is always a good idea when conducting international fieldwork.

Appropriate fieldwork equipment and supplies should be taken to ensure that if things do go wrong you could fix it. Backing up your data is extremely important. When doing fieldwork, things can easily get lost, broken or stolen. It is important that you arrive prepared with enough equipment that you can still successfully gather information if something doesn't go according to plan. At each historical photo point that I located, I took photos with three different cameras just in case something happened. Also, every time I was back in town I would back up my digital photos. I brought extra batteries, film memory cards, field notebooks, writing utensils, and the list goes on. Personally, I should have brought more rulers. I lost three rulers, two of which were not mine, while doing vegetation sampling because I would put them on the ground while I was writing field notes and then leave them there and continue hiking. I was also lucky in that I only had one significant equipment malfunction: One of my camera bodies stopped working, but after taking it apart and putting it back together, it started working again. As well as additional fieldwork supplies, any international traveler should carry their own first aid kit with appropriate medications and tools. It is important to be prepared in case something does go wrong.

Despite the challenges, the skills and knowledge acquired through international fieldwork is an invaluable experience to any geographer. The experience and education gained through international fieldwork cannot be taught in a lab. It is an experience of a lifetime.

3.6 Data Analysis

3.6.1 Vegetation Communities – Levels of Biodiversity

Indicator species were extremely important for my analysis, as they allowed me to reconstruct the spatial distribution of the vegetation communities within my study area. However, as well as the distribution, one of the primary objectives of this thesis is to determine the effects of this landscape change on biodiversity. Therefore, it was important that I determine which vegetation communities that I encountered during my fieldwork house a high level of biodiversity, which indicate disturbance, and which are identified as fragile – with a high level of endemic and endangered species.

In 2002, the 6th Conference of Parties to the Convention on Biological Diversity accepted the Global Plant Conservation Strategy (Ma *et al.*, 2007). The primary goal of this approach is to identify the most significant areas of floral diversity through using species-based criteria, including levels of endemic and endangered species, species richness and other ecosystem-based approaches (Ma *et al.*, 2007). In accordance with the priorities of the Global Plant Conservation Strategy, Ma *et al.* (2007) documented the floral diversity of the Yunnan Great Rivers Project area. Within the YGRP, Ma *et al.* (2007) identify ninety-eight endangered plant species, with the families of Liliaceae, Magnoliaceae and Ranunculaceae having several species on the list. Pinacaeae is also noted on the list with 3 endangered species. There are 703 species identified as endemic within the YGRP and in the areas immediately surrounding it. Families Asteraceae, Ranunculaceae, and Scrophularuaceae all have over 50 endemic species within the YGRP. The genus *Rhododendron* is also noted for having a high level of endemic species within northwestern Yunnan. Ma *et al.* (2007) note that areas of high endemism within the YGRP showed a strong correlation to the areas with high levels of endangered species.

Ma *et al.* (2007) discuss the species richness found in the vegetation types that occur within northwestern Yunnan. They identify the habitats with the highest levels of endangered species as being Evergreen Broadleaf Forest, the Alpine Meadow, Conifer Forest and Mixed Forest. Endemic species are found in the highest levels in Evergreen

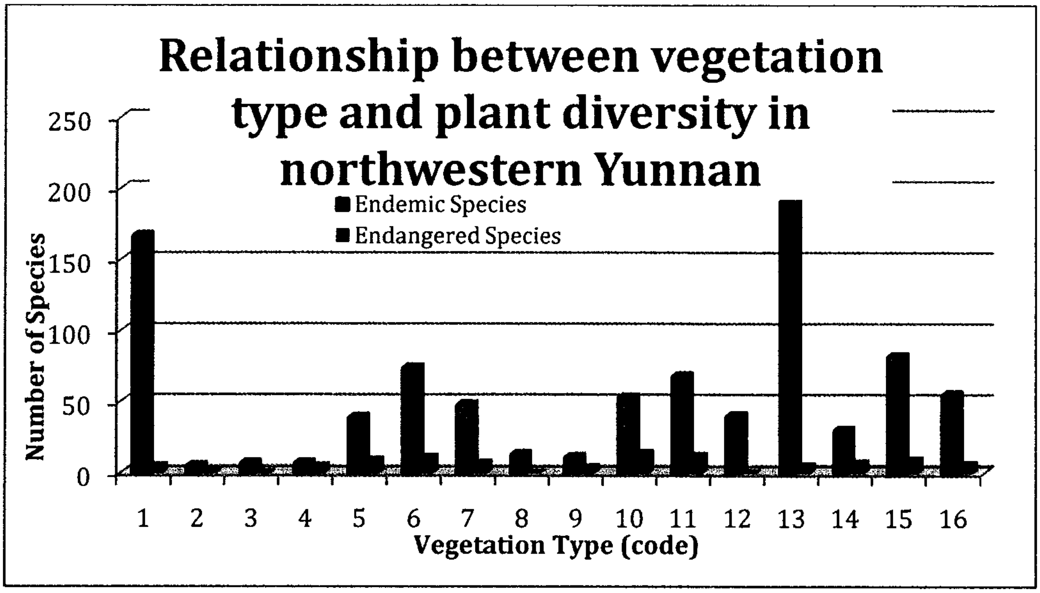


Figure 3.3 The relation between vegetation types and plant diversity in northwestern Yunnan. This chart is adapted from that found in Ma et al. (2006). The vegetation types are as follows: (1) Evergreen Broadleaf Forest; (2) Cold Sclerophyllous Oak Forest; (3) Dry/Hot Valley Sclerophyllous Forest; (4) Deciduous Broadleaf Forest; (5) Warm Conifer Forest; (6) Temperate Conifer Forest; (7) Mixed Coniferous and Broadleaf Forest; (8) Bamboo; (9) Warm Sparse Woodland; (10) Cold Scrub; (11) Dry/Hot Scrub; (12) Subalpine Meadow; (13) Alpine Meadow; (14) Alpine Scree; (15) Grassland; (16) Other (wetland, aquatic and rock outcrop habitats).

Broadleaf Forest, Subalpine Meadow, Alpine Meadow, and Alpine Scree. **Figure 3.3** shows the number of endemic and endangered species found in each vegetation type.

Incidentally, the vegetation types that house the highest number of endemic and endangered species are on the opposite extremes of the vegetation communities present in northwestern Yunnan with reference to the elevation-temperature gradient. The subtropical evergreen broadleaf forest appears in the warmer, lower altitude environments, while the alpine meadows and screes occur in the colder, high altitude environments on the high mountains of northwestern Yunnan. Because of the high altitude and arid environment of the First Bend of the Yangtze River, there is little evergreen broadleaf forest noted within the area of my study.

Within the First Bend of the Yangtze, I noted several of the vegetation communities outlined by Ma *et al.* (2006). For each vegetation community that I encountered, I needed to determine the level of biodiversity that it enclosed in order to conservation priorities. **Table 3.2** (p.61-63) shows the various vegetation communities that I saw during my fieldwork, as well as their expected distribution, the environmental characteristics that they are found in, the species that are present and the conservation priority that I have given to each classification. The characteristics of each vegetation community have been adapted from Li and Walker (1986).

3.6.2 Depicting Landscape Classifications

After returning from the field photo pairs were mapped and entered into a GIS database. Digital photos were loaded into a photo database and film photographs were scanned at high resolution and added to the same database. I used CorelDRAW X4 as image-processing software to match my photo pairs through layering photo pairs, aligning, and cropping with similar methodology to Zier and Baker (2006).

Using CorelDRAW X4, I divided each photo into land use classes and distinguishable vegetation communities. Each classification was given a specific colour and/or pattern. These colours and patterns were used throughout the analysis of the photo pairs. **Figure 3.4** (p.64) shows the colour of each landscape classification. A striped (pink) pattern indicates a human impact and a dotted pattern represents a mixture of landscape classifications. The colours shown in the pattern indicate the types of landscape classification that are mixed.

Table 3.2 The primary vegetation communities encountered during my fieldwork. Included in this table is the expected distribution of each vegetation community, the environmental characteristics of their expected distribution, the species that are present, and the value of each vegetation community to the conservation of biodiversity.

Vegetation Type	Distribution	Characteristics		Species Present	Cons. Priority
Sclerophyllous *Quercus* Forest (3 types)	- unique to the slopes of the Yangtze River (cold/arid winters) - 2600-4300m asl	- plants are xerophytes, demonstrate cold-resistant properties - Leaves: small, leathery, serrate edges, wooly beneath - Bark: rough - Tree Structure: twisted, crowded	- high humidity - acidic soil - 70% canopy - trees 15-25m tall - species-rich	- *Quercus aquifolioides* - *Sorbus koehneana* - *Sorbus rehderiana* - *Rhododendron*	MEDIUM
			- arid environment - thin soil - less acidic soil - stunted forest, trees reach 8m	- *Quercus aquifolioides*	
	- lower slopes of the Yangtze River - 1000-2000m asl - arid environment, winter temperatures are not as cold as at higher altitude		- grow on limestone - understory = species-rich	- *Quercus cocciferoides* - *Quercus franchetii* *Quercus rehderiana* - *Cyclobalanopsis glaucoides*	
Shrubland (2 types)	- common vegetation type along the Yangtze River	- soils have a low organic content		*Opuntia monacantha-Euphorbia royleana* shrubland - *Acacia farnesiana* - *Carissa spinarum* - *Erythrina spp.*	MEDIUM
	- broadly distributed throughout northwestern Yunnan on slopes of major river valleys	- mixed deciduous-evergreen shrubland - commonly xerophytes		*Vitex negundo* shrubland - *Terminalia franchetii* - *Phyllanthus emlica* - *Bombax malabarica*	
Warm *Pinus* Forest	- primarily montane - commonly occurs from 2500-3000m - above *Pinus yunnanensis* forest	- common in areas of human disturbance - areas occupied with warm *Pinus* forest would be Evergreen	- low temperature s - low sunlight	*Pinus armandi* forest - *Pinus densata* - *Cupressus duclouxiana* - *Quercus rehderiana* - *Rhododendron delavayi*	LOW
			- soils dry and infertile	*Pinus yunnanensis* forest	

		Broadleaved Forest and Sclerophyllous Forest if not disturbed	- soil with low organic content - forest = structurally simple - often degraded by grazing and other disturbance to open woodland	(2 variants) 1) *Pinus yunnanensis- Cyclobalanopsis delavayi* forest - *Castanopsis delavayi* - *Quercus spp.* 2) *Pinus yunnanensis* – sclerophyllous *Quercus* forest - *Q. longispica* - *Quercus guyavifolia*	
Montane Conifer Forest	- 3000-3400m asl	- Drought resistant - Above *Pinus yunnanensis* forest - *Pinus densata* is commonly used to reforest these areas		Montane *Pinus densata* forest - *Abies spp.* - *Picea spp.* - *Larix spp.* - sclerophyllous *Quercus spp.*	MEDIUM
	- 2700 – 4000m asl	- floristically rich - generally a secondary forest, after the destruction of an *Abies* or *Picea* forest - requires a thick layer of brown soil and an abundance of decaying organic material		*Larix* forest - *Larix potaninii* var. *macrocarpa* - *Larix speciosa* - *Usnea longissima spp..* - *Quercus spp.* - *Betula spp.* - *Abies spp.* - *Picea spp.* - *Pinus spp.* - *Rhododendron spp.*	
	- area of the First Bend of the Yangtze in shady places at altitudes of 3100-3800m	- soil must be high in organic matter		*Picea likiangensis* forest - *Abies spp.*	
	- higher slopes of the upper Yangtze River	- able to survive in a climate that is more extreme than that which *Picea* is able to survive		*Abies* forest - *Abies georgei* - *Abies forestii* - *Picea likangensis* - *Larix potaninii* var. *australis* - *Quercus aquifolioides* - *Rhododendron spp.*	

Montane Shrubland	- Approx. 4000m asl - close to and above the forest limits at the treeline	- composition varies greatly - typified by dominant species	- rocky slopes that are more exposed to both sun and wind	*Sabina squamata* shrubland	HIGH
			- commonly grow above *Abies* forests - exposed to cold/windy conditions all year	*Rhododendron spp.* shrubland	
Alpine Environment	- Approx. 4000m asl - close to and above the forest limits at the treeline	- high levels of endemic and endangered species - high threat to biodiversity as climate change causes forest encroachment - commonly occur in mosaic with alpine shrublands - alpine shrublands overtake the alpine meadows - variants are determined by dominant spp. - species-rich		*Kobresia prattii* meadow - *Leontopodiam spp.* - *Potentilla spp.* - *Meconopsis spp.*	VERY HIGH
				Roscoea alpina-Gueldenstaedtia yunnanensis meadow	

* Conservation Priority was named through taking into account the level of biodiversity, the number of endemic and endangered species, and the resilience of each ecosystem type, as well as any identified immediate threats.

3.6.3 Qualitative Assessment – Visual Indicators

For each of the photo pairs, I first subjectively assessed for notable changes. Qualitative analysis of photo pairs included the identification of present land use and vegetation types. Each category (Refer to **Table 3.3**, p.65) was assessed for its stability, i.e. land use and vegetation categories were marked as increasing, decreasing, or stable and the degrees of change were indicated. The degree of change was assessed similarly to the definitions laid out by Zier and Baker (2006), who classify a moderate change as one where the boundary transition is local and did not move by more than approximately 50 meters. An extensive change is a directional change of greater than 50 meters, or when a major disturbance has resulted in the loss of a land use or vegetation type that was previously seen. Any increase or decrease in a land use or vegetation community was documented as

Figure 3.4 Colour-coded landscape classifications used for photo analysis and interpretation

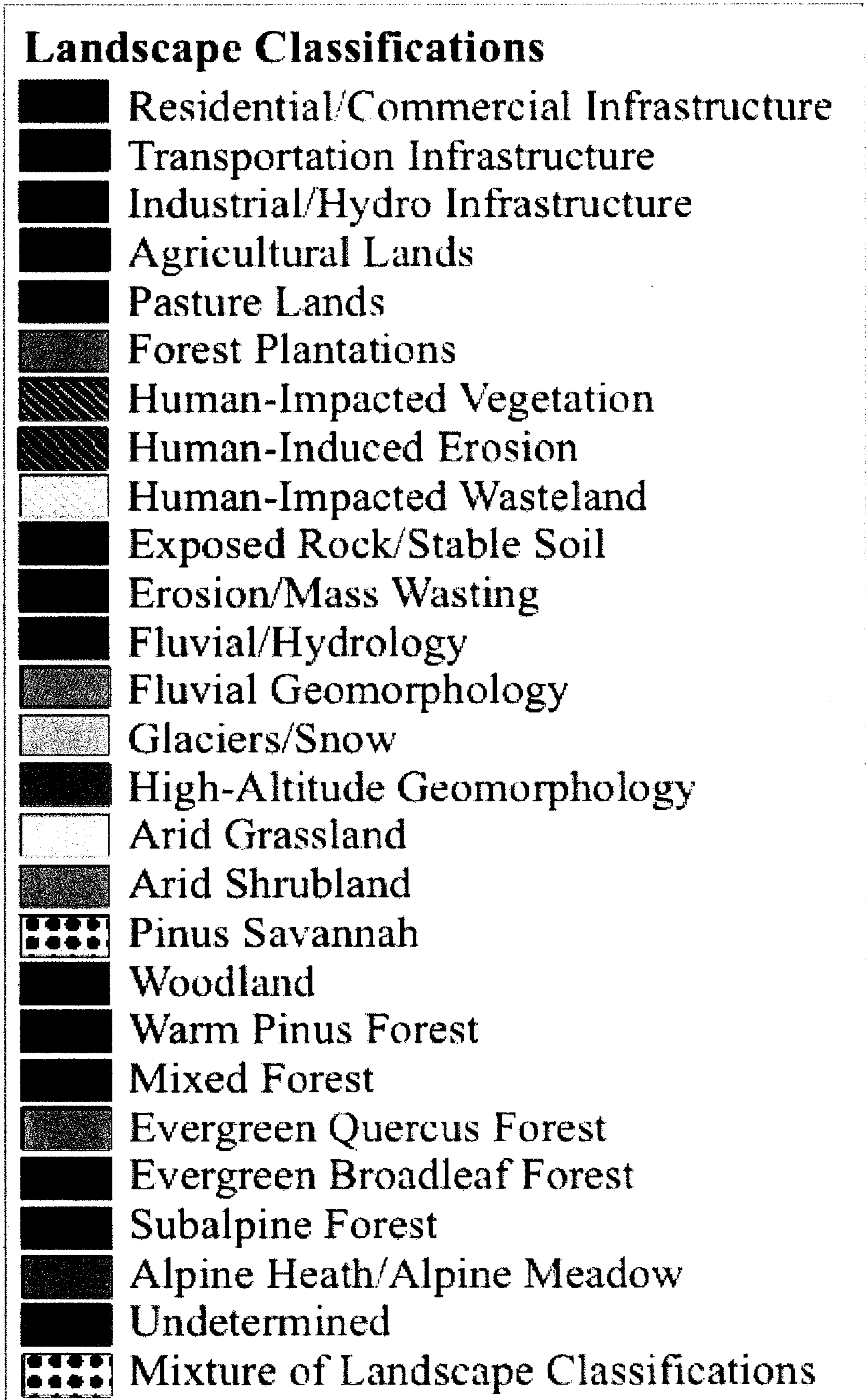


Table 3.3 Land Use, Landscape Features, and Vegetation Types in Northwestern Yunnan (Moseley, 2004; Xu & Wilkes, 2002)

	Category	**Definitions**
Land Use	Settlements/Infrastructure	Evidence of residential, commercial and infrastructural changes
	Agricultural Lands	Land used for growing crops
	Grazing Lands	Land used for grazing
	Forest Plantations	Areas of evident reforestation
	Human-Induced Erosion	Unstable geomorphology that is the result of human action, ie. Road implementation.
Landscape Features	Exposed Rock/Stable Soil	Stable geomorphology
	Erosion/Mass Wasting	Geomorphology that does not appear to be stable
	High-Altitude Geomorphology	Geomorphology present in the alpine environment, above the treeline.
	Fluvial Geomorphology	Geomorphology surrounding rivers, lakes; the exposed geomorphology of the floodplain
	Glaciers/Snow	Glacial ice, seasonal snow
	Fluvial Hydrology	Rivers, streams
Vegetation Communities	Arid Grassland	Low elevation grasslands (grazed or ungrazed)
	Arid Shrubland	Low elevation shrublands (below timberline)
	Woodlands	Open stands of trees at lower altitudes than coniferous forest
	Warm *Pinus* Forest	Low elevation coniferous forest dominated by *Pinus yunnanensis, Pinus densata*
	Mixed forest	Belt of endangered plant species (*Taxus yunnanensis, Psuedotsuga forrestii*)
	Evergreen *Quercus* forest	Forests dominated by *Quercus* spp, commonly on north-facing slopes
	Evergreen broadleaf forest	Low elevation forests (*Cedrus, Alnus nepalensis*)
	Subalpine forest	High elevation forest dominated by *Abies, Larix, Picea* and *Quercus*
	Subalpine meadow	Canopy openings in the high elevation forests containing herbaceous species, generally occurring on valley bottoms
	Alpine heath	Shrubland communities above the upper treeline dominated by *Juniperus* and *Rhododendron* species, contains *Salix* and *Caragana* spp.
	Alpine meadow	Herbaceous communities above the treeline *Caragana spp., Saussurea spp., Fritillaria delavayi, Meconopsis.*

light, moderate, or extensive. This assessment of landscape change helped to distinguish large-scale landscape change from localized change.

3.6.4 Quantitative Assessment – Photo Grid Analysis

Repeat photography has been proven to provide useful qualitative data; however, ground-based repeat photography can also be used as a method for quantitatively assessing landscape changes over time. For my photographic analysis, I used two methods to quantitatively assess landscape changes.

The first method that I used was Simple Grid Analysis. Hall (2002b) describes this method as a tool to monitor landscape change on a reasonably fine scale. Simple Grid Analysis measures the area covered by different entities on the negative, or photograph itself. This method was possible due to the very large negatives of the original photographs, i.e. 4x6 inches (10.2 x 15.2 centimeters), which provided extremely detailed images. A grid overlay was placed on both the historical and the recent photo of each photo set. Each land use and vegetation category was highlighted and the percentage of photo area covered by each category was considered. **Figure 3.5** (p.67) shows an example of the process of Simple Grid Analysis using the historic photograph from Photo Set #19.

Simple Grid Analysis serves well as a tool for comparing different landscape features on the single plane of the photograph; however, in order to quantify and compare changes in vegetation communities and land use within landscape photos, themselves, it is important to take into account the varying area occupied by a photographed entity on different planes at different distances from the photo point. The second method of quantitative photo analysis that I used was designed to account for the actual size of the photographed entities, to allow for a quantitative comparison, taking into account the

Figure 3.5 Historic Photo #19 showing simple photo grid analysis. The original photo taken in 1923 by Joseph Rock (left), the photo overlaid with a simple grid (middle), and the photo displayed with the colour-coded classifications of land use and vegetation communities (right).

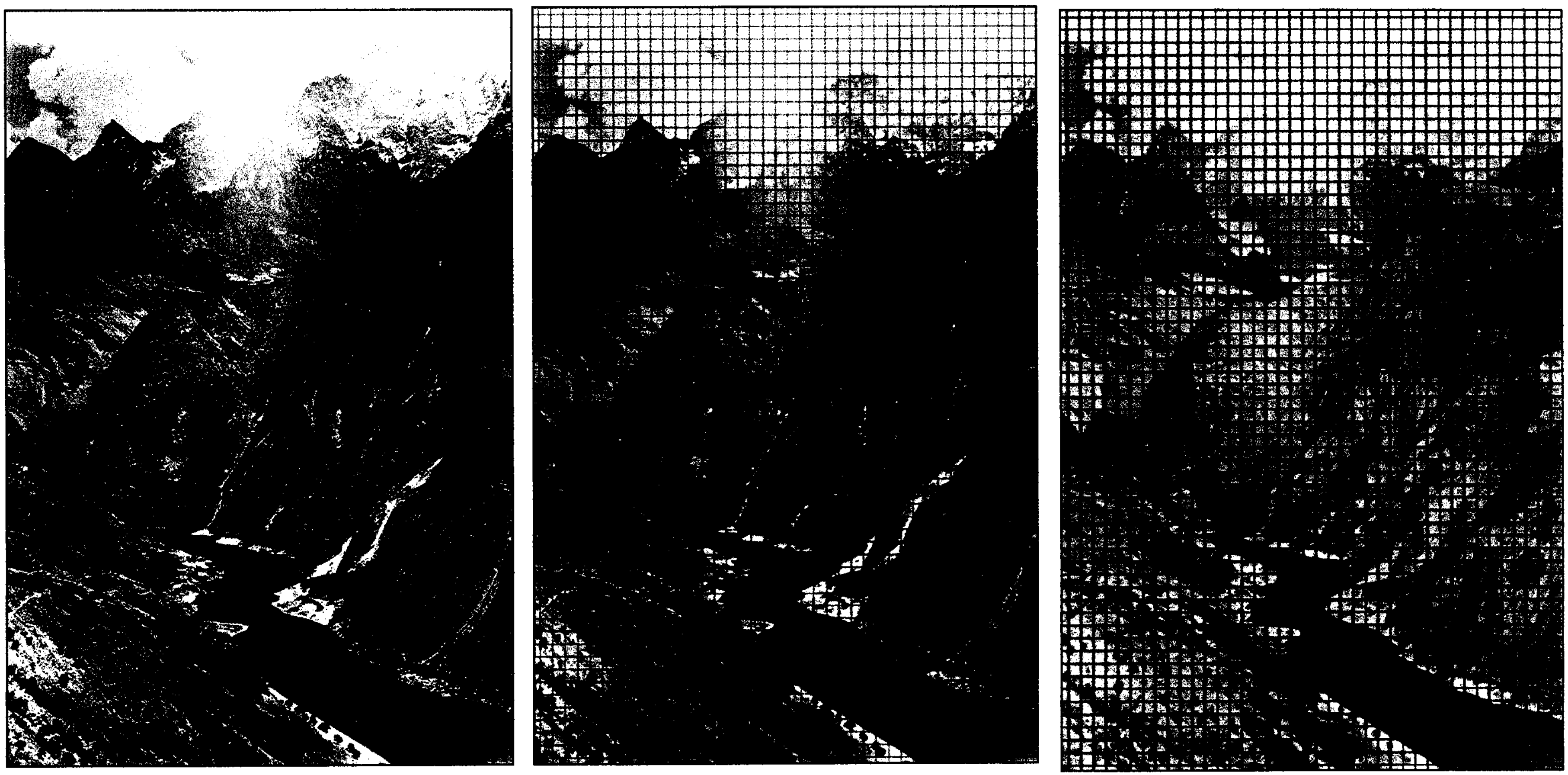
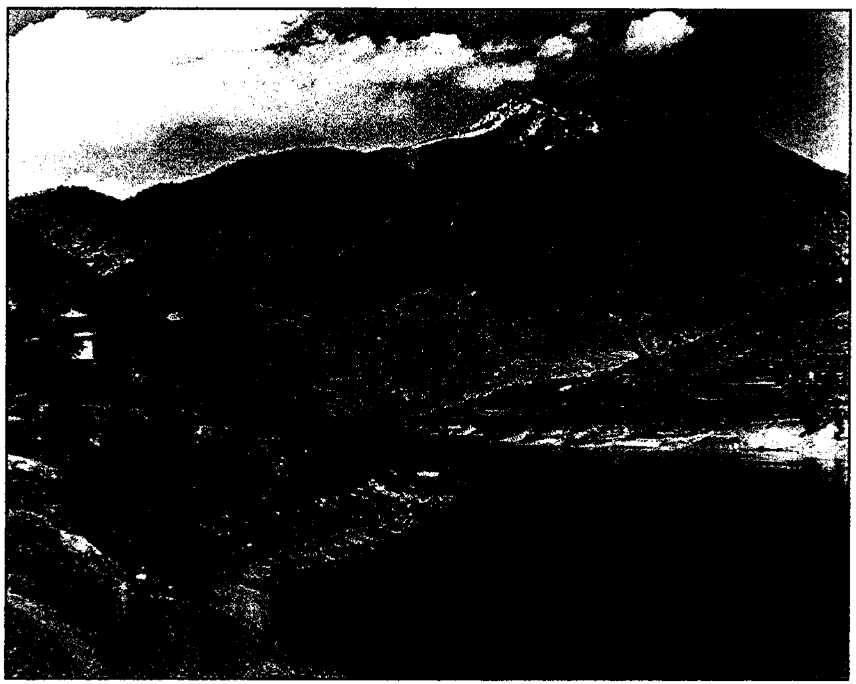
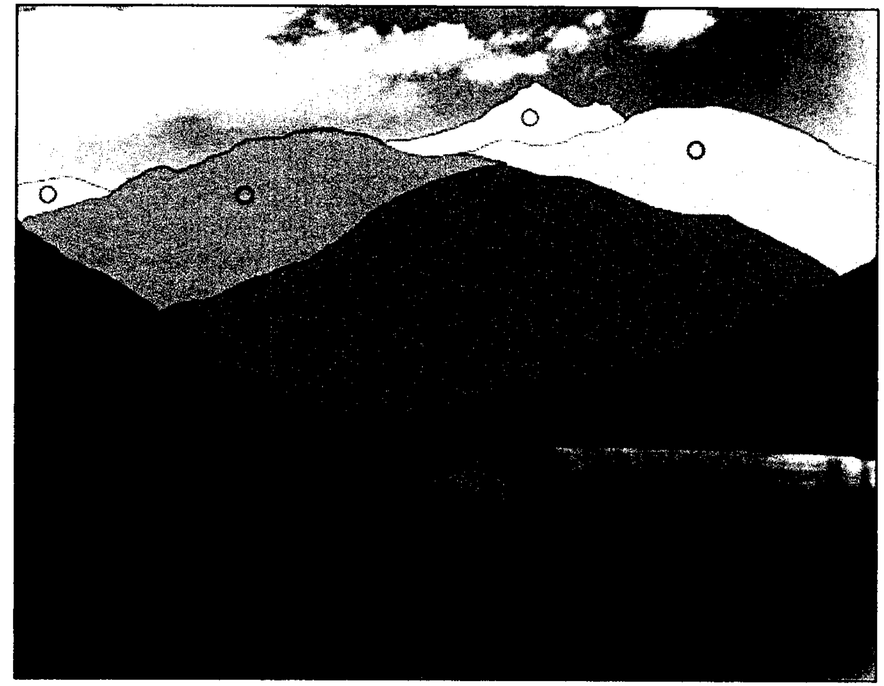


Figure 3.6 Historic Photo #14 showing the steps of scaled photo grid analysis. The original photograph taken in 1923 by Joseph Rock (left), Photo #14 with the different topographic layers categorized for grid size (middle), a pictorial representation of the grid sizes used on each area based on distance from the photo point (right).





varying distances between photographed entities and the photo point. Scaled Grid Analysis is based on the use of grid planes calibrated to fit the topography of the landscape. Each grid plane is scaled based on the distance from the photo point to the plane of the landscape feature. **Figure 3.6** (p.68) shows an example.

Using Google Earth[9] to establish the coordinates of different layers in the photograph (latitude and longitude in degrees, minutes, seconds, and altitude in meters above sea level), I calculated the distance of each grid plane to the photo point by using trigonometry, determining the horizontal distance between coordinates of latitude and longitude, and then

First, I calculated the horizontal distance from the photo point to the grid plane using the following formula:

$$\Delta D_h = ACOS(SIN(Lat1) * SIN(Lat2) + COS(Lat1) * COS(Lat2) * COS(Lon2 - Lon1)) * 6371 \quad (1)$$

The mean radius of the earth is 3671km. I used this value to find my horizontal distances. Once I had the horizontal distance calculated, I found the total distance, $D_h + D_v$, from the photo point to each grid plane by factoring in the difference in altitude between the two points using the following equation:

$$\Delta D_v = (Alt1) - (Alt2) \quad (2)$$

$$D = \sqrt{(\Delta D_h)^2 + (\Delta D_v)^2)} \quad (3)$$

Where ΔD_h is the horizontal distance between points, calculated by latitude and longitude coordinates, and ΔD_v is the vertical distance, calculated by determining the difference between altitude points.

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[9] I acknowledge the limitations to using Google Earth as the source for latitude, longitude and altitude points. The accuracy of Google Earth is approximately 90m, depending on the area of interest. Because my landscape photos cover large geographic areas, I feel that this is an acceptable limitation in my analysis.

Using the calculated distances (D), I created a ratio for grid size by determining an appropriate grid size for the center grid plane and then adjusting the grid size of each other plane using a simple ratio:

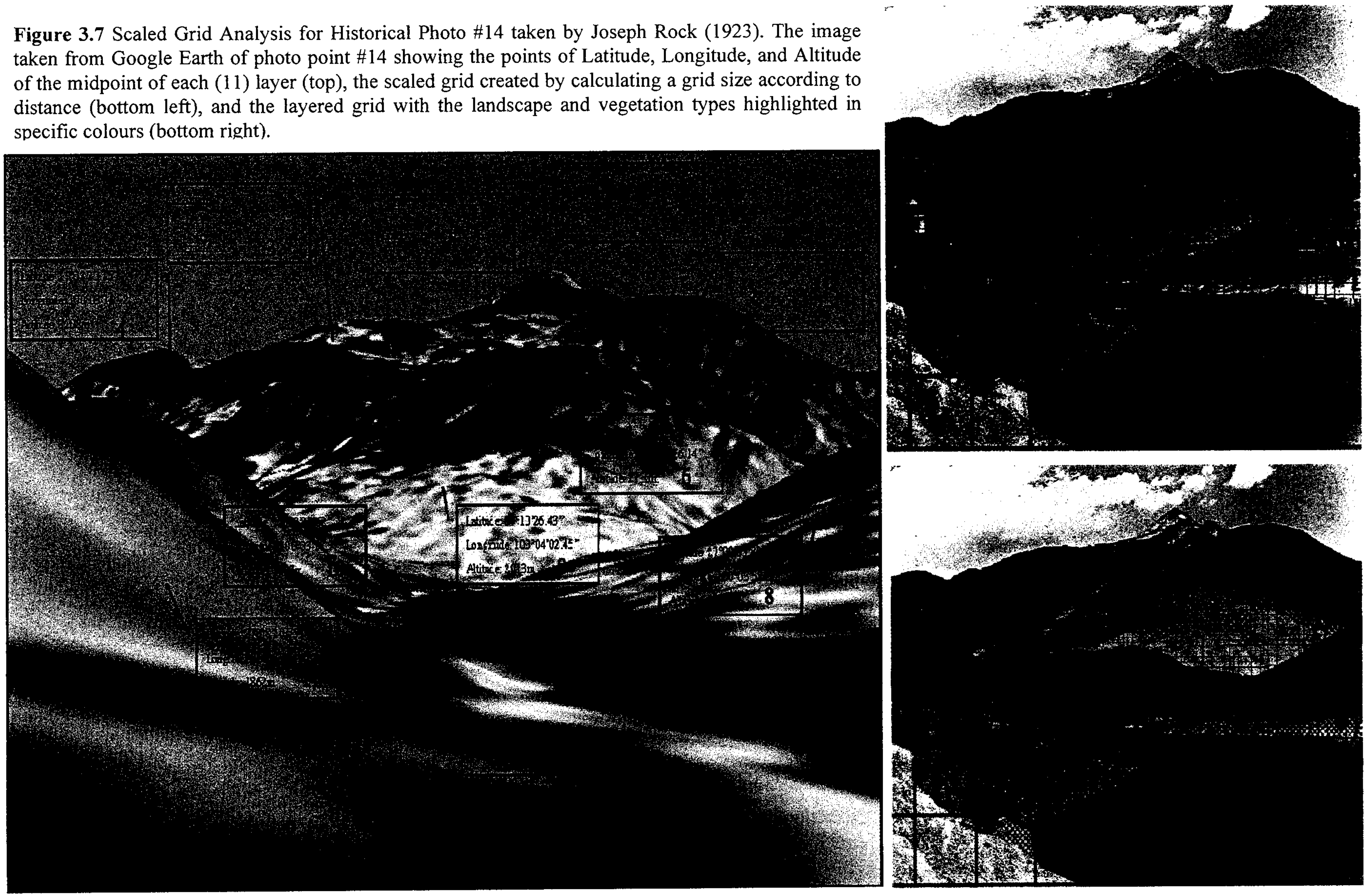
$$S_1 * D_1 = S_2 * D_2 \quad (4)$$

$$S_2 = \frac{S_1 * D_1}{D_2} \quad (5)$$

Where S is the length of a grid side, and D is the distance from the layer's plane to the photo point. **Figure 3.7** (p.71) shows a calculated scaled grid for Photo Set #14.

Scaled photo grid analysis helped to establish a more detailed value for the area of each landscape entity. Using this system, I was able to quantify landscape changes at a much finer resolution by accounting for changes in actual subject area, as opposed to the area that the subject covers on the photograph itself. Even more detail can be added through increasing the number of planes in the analysis: the greater the number of planes being quantified in the photograph, the greater the detail of the quantitative data available within each photograph. Simply put, Scaled Grid Analysis addresses the problem of weighting that is encountered using Simple Grid Analysis. Using the simple grid, areas closest to the photo point are overrepresented in comparison to those at a distance. The scaled system allowed for a more accurate comparison; however, this method also has its limitations (refer to section **5.2.2**). Comparing the areas of specific photograph topics allowed for a quantitative analysis of the changes that have occurred with regards to the frequency and distribution of land use categories and vegetation communities.

Figure 3.7 Scaled Grid Analysis for Historical Photo #14 taken by Joseph Rock (1923). The image taken from Google Earth of photo point #14 showing the points of Latitude, Longitude, and Altitude of the midpoint of each (11) layer (top), the scaled grid created by calculating a grid size according to distance (bottom left), and the layered grid with the landscape and vegetation types highlighted in specific colours (bottom right).



3.7 Summary

Chapter 3 discussed my fieldwork preparation, as well as the methodology that I used during my rephotography fieldwork in northwestern Yunnan. I also provided a narrative of the challenges that I faced while conducting international fieldwork in China. Further, I discussed the methods used for my data analysis. I explained my vegetation analysis, as well as the challenges of using historical data. In addition, I explained the methods that I used to interpret the photographs, including qualitative analysis through presence/absence analysis and boundary transitions, and quantitative analysis through both simple and scaled grid analysis.

Using the methods introduced in Chapter 3, Chapter 4 presents the results of this thesis. First, I detail the point locations of my rephotography study. Next, I discuss the historical literature that is offered by Frank Kingdon-Ward and Heinrich Handel-Mazzetti. I also offer detailed information about my photo sets, including their locations, and the results of the quantitative and qualitative analysis.

4.0 Results

4.1 Introduction

While Chapter 3 focused on the methodology that I used for both my fieldwork and analysis, Chapter 4 introduces the reader to the results of my landscape analysis and rephotography study, including the photo sets that I used to analyze the land use and vegetation community changes for the First Bend of the Yangtze, the qualitative analysis that I conducted on the photo sets, and the quantitative analysis that I conducted using Simple Grid Analysis and Scaled Grid Analysis. Also, I present a summary of the results of my literary review of the biogeographical writings of Frank Kingdon-Ward and Heinrich Handel-Mazzetti, as well as the results from my vegetation sampling. Within this chapter, I provide detailed results for three of my twenty-two photo sets to allow the reader to better understand my process of analysis and interpretation.

4.2 Photo Locations

Twenty-two photo sets were selected to complete this rephotography study of the First Bend of the Yangtze. Joseph Rock took the original photographs used for this landscape analysis around 1923. I retook ten of his photographs in 2008. I also used several of Rock's landscape photographs that had been retaken by Robert Moseley of the Nature Conservancy as part of the Yunnan Great Rivers Project. Robert Moseley retook these photographs from 2003-2005. **Figure 4.1** (p.74) shows a map of the photo points. Each photo set is numbered from 1 to 22, starting at the furthest upstream location (top left) and heading downstream. The photographs taken by Rock (1923) and myself (2008) are noted in light blue, those photographs taken by Rock and Moseley (2003) are portrayed in

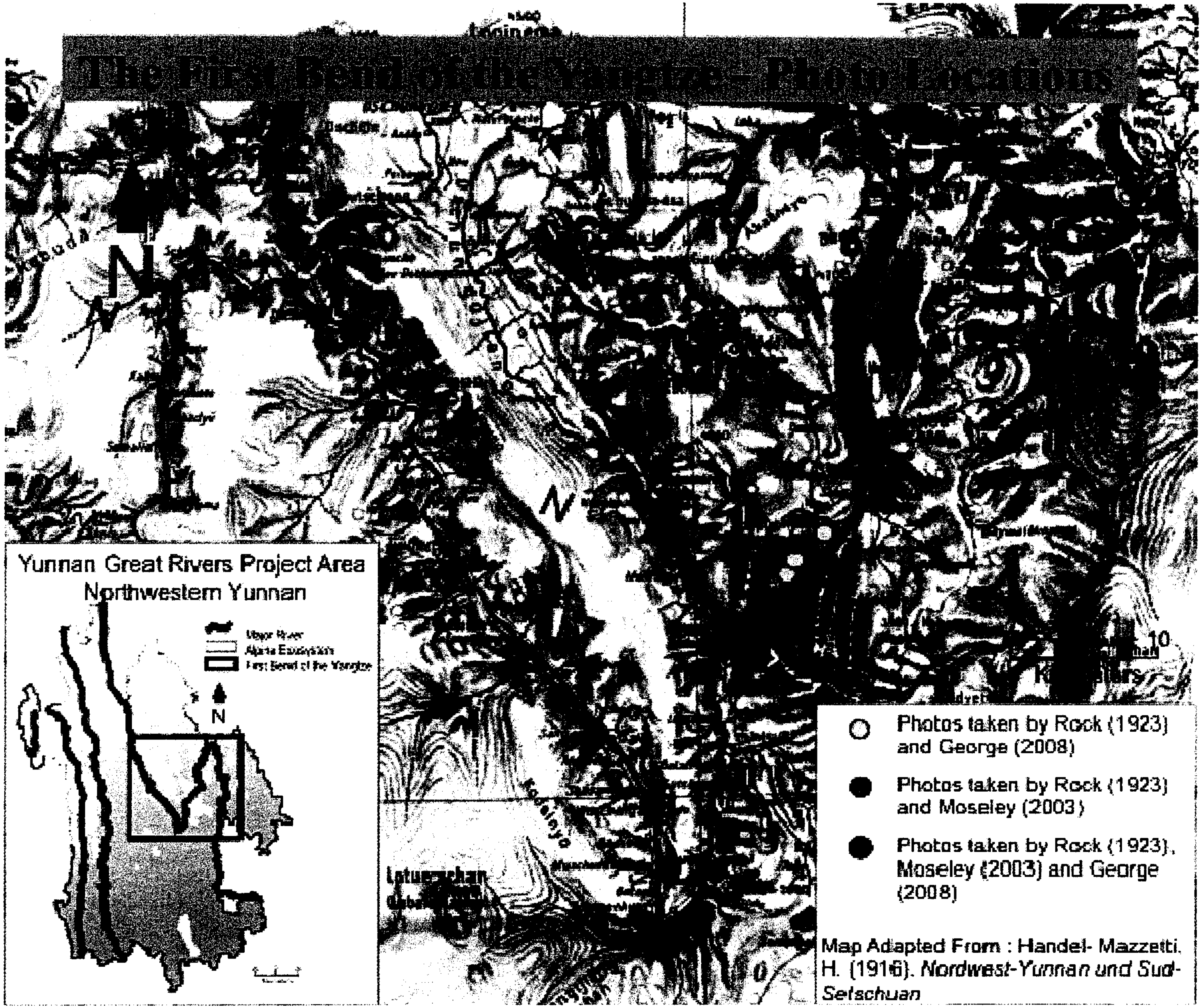


Figure 4.1 A map of the First Bend of the Yangtze showing the location of each photo point. The photographs were all originally taken by Joseph Rock in 1923. The photographs retaken by George (2008) are shown in light blue, retaken by Moseley (2003) are noted in medium blue, and those photographs retaken by both are evident in dark blue.

medium blue, and those photographs taken by Rock (1923) and then retaken by both Moseley (2003) and myself (2008) are shown in dark blue.

The purpose of including the additional photo sets, taken by only Rock (1923) and Moseley (2003-2005), is to ensure that the conclusions that I draw from the photo sets that I contributed to and analyzed more thoroughly, do reveal reoccurring changes to the spatial land use distributions in northwestern Yunnan. By including these photo sets, and qualitative analysis of each of these photo sets, I intend to strengthen the detailed conclusions that I draw from comparing the landscape photographs that I took with the originals that were taken by Joseph Rock. Within this chapter, I will discuss three photo sets in detail. Data for the additional photo sets are available in the appendices.

Table 4.1 An index of each photo set identifying the number, photographer, photo location and the appendices where further information about the photo set is available.

Photo Point	Photographers			Photo Location		Appendix					
				Latitude °N	Longitude °E	A	B	C	D	E	F
	Rock	Moseley	George	27°34'45.1"	99°31'25.0"	✓	✓	✓	✓	✓	
	Rock	Moseley		27°34'02.5"	99°31'45.6"	✓		✓			
	Rock	Moseley	George	27°33'37.1"	99°32'11.5"	✓	✓	✓	✓	✓	✓
	Rock	Moseley		27°28'28.2"	99°34'05.1"	✓		✓			
	Rock	Moseley		27°25'40.0"	99°35"38.2"	✓		✓			
	Rock	Moseley		27°20'25.8"	99°38'29.4"	✓		✓			
	Rock	Moseley		27°19'16.2"	99°38'22.2"	✓		✓			
	Rock	Moseley	George	27°05'17.9"	99°52'01.6"	✓	✓	✓	✓	✓	
	Rock	Moseley		26°56'09.9"	99°57'47.3"	✓		✓			
	Rock	Moseley		26°52'08.2"	99°57'52.5"	✓		✓			
	Rock	Moseley		26°52'37.4"	99°59'02.3"	✓		✓			
	Rock	Moseley		26°53'08.8"	100°00'17.9"	✓		✓			
	Rock	Moseley		26°55'51.1"	100°03'21.4"	✓		✓			
	Rock	Moseley	George	27°08'01.9"	100°03'15.0"	✓	✓	✓	✓	✓	✓
	Rock	Moseley		27°10'00.2"	100°03'32.6"	✓		✓			
	Rock	Moseley	George	27°10'25.1"	100°03'55.7"	✓	✓	✓	✓	✓	✓
	Rock	Moseley	George	27°10'25.2"	100°04'29.3"	✓	✓	✓	✓	✓	
	Rock	Moseley		27°10'25.3"	100°04'29.1"	✓		✓			
	Rock		George	27°10'37.2"	100°05'01.8"	✓	✓	✓	✓	✓	
	Rock		George	27°11'49.6"	100°06'33.9"	✓	✓	✓	✓	✓	
	Rock		George	27°11'50.9"	100°06'38.9"	✓	✓	✓	✓	✓	
	Rock		George	27°15'04.2"	100°08'46.0"	✓	✓	✓	✓	✓	

Table 4.1 (p. 75) lists each photo point, reveals the photographers who contributed to the photo set, the latitude and longitude of the photo point, and where the reader can access detailed information about each photo set. **Appendix A** provides the reader with copies of each photograph used to conduct this rephotography study. **Appendix B** provides the detailed landscape information that I collected for each of the photo points. In **Appendix C**, I provide an overview of conspicuous landscape features, as well as the evident differences within each photo set. The data in **Appendix D** is more structured and I use presence/absence, stability and degrees of change to assess the land use and vegetation community changes depicted in the photo sets. The ten sets that included my own photograph were analyzed and interpreted using Simple Grid Analysis. For data on all photo sets analyzed using Simple Grid Analysis, consult **Appendix E**. Finally, **Appendix F** offers the results of the Scaled Grid Analysis that I conducted on three photo sets. Within both **Appendix E** and **Appendix F**, I offer the reader the photo sets with the landscape classifications and grids overlaid, as well as the number of grid squares occupied by each landscape classification and that area represented as a percentage of the total number of squares occupied by landscape classifications. I conducted photo analysis and interpretation on 22 photo sets. I chose to present a detailed analysis for three of my twenty-two photo sets within this chapter. These three photo sets touch on the prominent landscape changes that I realized through my analysis and interpretation. The three photo sets that I am presenting to the reader within this chapter are Photo Set #19, Photo Set #16, and Photo Set #3.

4.3 Fieldwork Results

Fieldwork was conducted in northwestern Yunnan during the early summer of 2008. In the field, a preliminary landscape analysis was conducted. This included documenting landscape characteristics around the location of each photograph, a detailed description of the location of each photo point, and the conditions that were present at the time that each photograph was retaken. As well, any apparent differences were cataloged. A summarized record of the field notes taken for Photo Set #3 is shown in **Table 4.2** (p.78). For a summary of the in-field notes taken for all of the photographs retaken by me in 2008, consult **Appendix B**.

4.4 Analysis of the Photo Sets

Within this chapter, I have included the analysis of three of my photo sets, Photo Set #19, Photo Set #16, and Photo Set #3. For each photo set, I present my qualitative results. Included in this is the methodology recommended by Zier and Baker (2006). These methods are explained in Chapter 3 on page 65. Next, I present the reader with the results of the Simple Grid Analysis that was conducted using the method described by Hall (2002b). Finally, for Photo Set #16 and

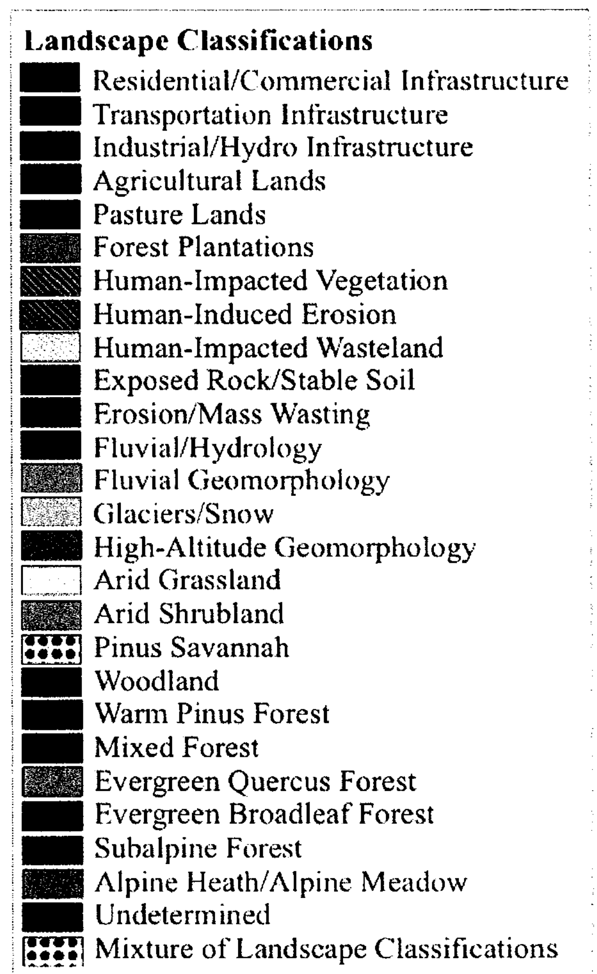


Figure 4.2 A legend depicting the colour-coded landscape classifications. For a larger format, consult **Figure 3.4** on page 64.

Table 4.2 In-field landscape information, including location, landscape characteristics and conditions. Adapted from Moseley (2006). For a detailed description of the in-field landscape information for each photo set, see **Appendix B.**

Photo Information	Explanation	Photo Set #19
Location	Description of the location and directions to photo point	Yangtze River, Tiger Leaping Gorge, Yulong Shan is on the right.
GPS	Latitude-Longitude, Altitude	27°10'37.2" N-100°05.01.8" E, 2160m
Orientation	Direction faced to retake photo (compass bearing)	24°
County	Political location of photo point	Lijiang County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, mixed forest, alpine forest, alpine heath and meadow, shrubland/grassland on the lower, steeper slopes
Land Cover	Dominant vegetation	Alpine spp. *(Rhododendron, Kobresia), Pinus densata, Abies, Picea, Pinus yunnanensis, Quercus spp.*, bamboo, shrubland and grassland spp.
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	Terraces for agriculture on left slope (hidden), pasture grazing possible in the grasslands and shrublands of the lower slopes
Infrastructure	Transportation, industrial and power infrastructure	Trails along slopes, right slope shows a horizontal line with a pipe (carrying water?), roadways present along river's edge, concrete transportation infrastructure protruding into river (erosion mitigation as well as parking lot/tourist information centre?)
Disturbance	Soil erosion, forest clearing, mining	Erosion along riverbank due to transportation infrastructure
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 13, 2008; 3:33 PM (UTC +8)[10]
Air Quality	A record of the weather conditions and light quality	Raining, cloudy, misty.
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	N/A

[10] UTC+8 refers to the time zone that is ahead of Greenwich Mean Time by 8 hours. This time zone includes all of the People's Republic of China. This was the local time during my rephotography study in northwestern Yunnan.

Photo Set #3, I present my Scaled Grid Analysis. I begin here with my analysis of Photo Set #19. To remind the reader, each landscape classification used for my analysis is coloured according to the legend shown in **Figure 4.2** (p.77).

4.4.1 Photo Set #19

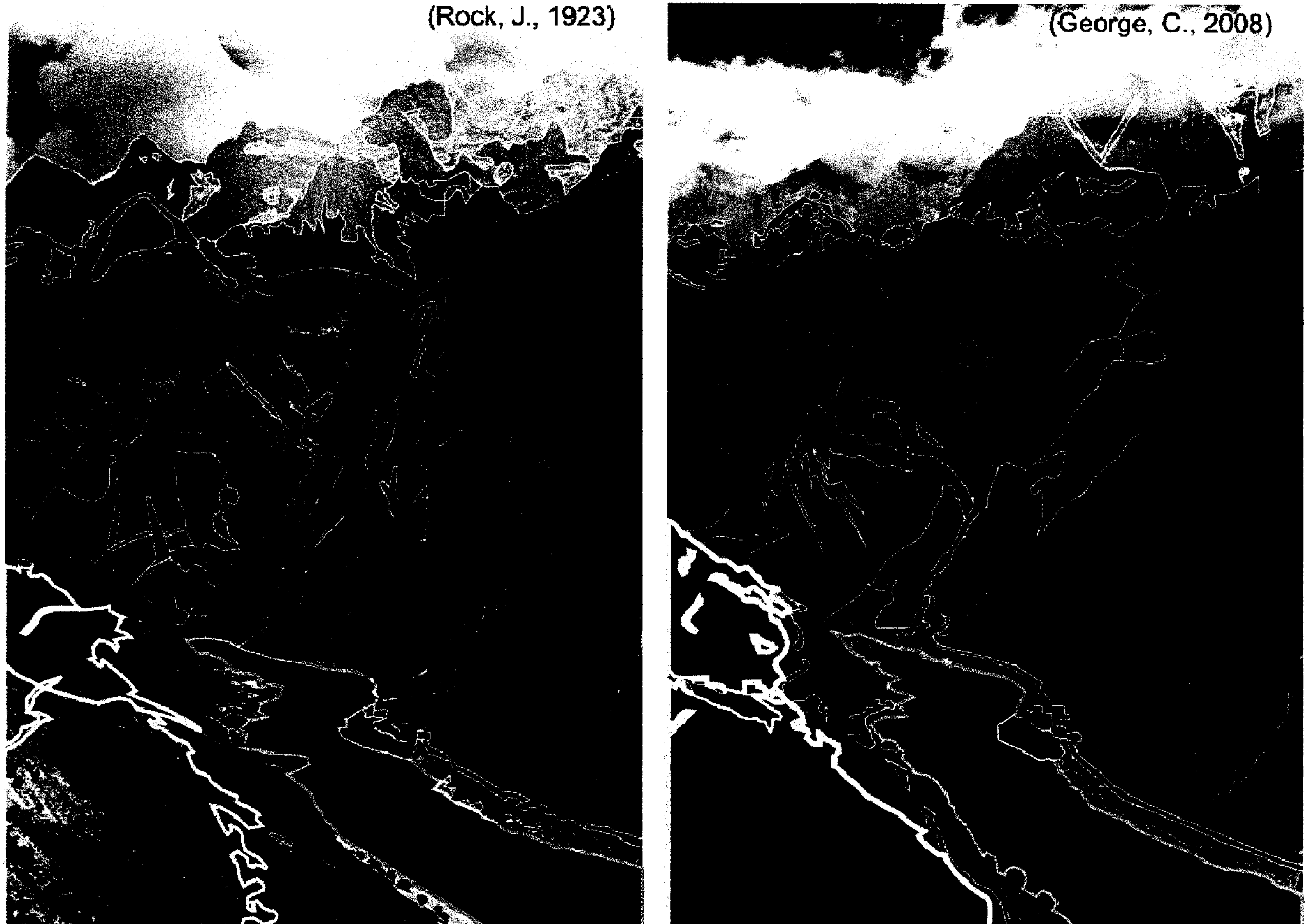
The photographs within this photo set are taken of the Yangtze River, looking downstream through Tiger Leaping Gorge (27°10'37.2" N, 100°05.01.8" E, 2160m). Yulong Shan is on the right. **Figure 4.3** (p.80) provides the unaltered photographs that make up this photo set.

4.4.1.1 Qualitative Analysis of Photo Set #19

Please refer to **Figure 4.4** (p. 81) while reading through this section about the qualitative analysis of Photo Set #19. Regarding the settlement pattern, there are a few buildings present in both photographs. In Rock's historical photograph, there are three houses standing on the right bank by the river (highlighted in magenta). In 2008, there are buildings in the same location; however, these buildings are commercial buildings, as the area on the right bank of the river has now become a major parking lot for tour buses. Many of the buildings are related to tourism, either tourist information centers, eateries for tourists, or offices for tourism companies. As well, on the left bank of the river, there is evidence of a village with a few houses that, while present in 2008, are not present in Rock's historical photograph. In addition to the houses on the left bank of the Yangtze River, there are also agricultural lands present in the 2008 photograph that did not exist in the historical photograph (highlighted in dark peach). Also, during my two hikes of the

Figure 4.3 Photo Set #19, taken of the Yangtze River, looking downstream through Tiger Leaping Gorge (27°10'37.2" N,100°05.01.8" E, 2160m)

Figure 4.4 Photo Set #19 with overlay marking notable landscape changes.



gorge, I encountered many herds of goats and sheep grazing on the left bank. Because this vegetation community shows no significant changes between photographs, both photographs showing a mixture of arid shrubland and arid grassland, I assume that the left bank of the Yangtze River in this area also offered acceptable grazing pasture in the early 1900s.

Within the historical photograph, dirt pathways line both sides of the lower banks of the Yangtze River. In the contemporary photograph, those pathways have been replaced by paved roadways. The dirt pathways that were present on the higher slopes in the historical photograph remain there through 2008. As well, in the photograph taken in 2008, there is a prominent horizontal line running across the upper slopes of the right bank. This pathway holds a pipeline that I suspect is carrying water down from the mountains. Other than the pipeline, there is no industrial or power infrastructure evident in either photograph.

There appears to be more glacial ice and snow within the high altitude region of Yulong Shan in the older photograph (shown in light blue). In the top right corner of the historical photograph, there is a mass of snow and ice that has decreased greatly by 2008. I hypothesize that this is partially due to the seasonal difference between when the photos were taken; however, the drastic change in glacial mass could indicate a trend of glacial retreat, caused by long-term warming or loss of precipitation. Also, the water level of the Yangtze River appears to be lower in the historical photograph, exposing more fluvial geomorphology (outlined in gold). This could also be the result of the seasonal difference between when the photographs were taken. There appears to be significant mass wasting taking place in the historical photograph, specifically along the right bank (highlighted in dark brown). By 2008, the mass wasting seems to have decreased, but the new rock faces

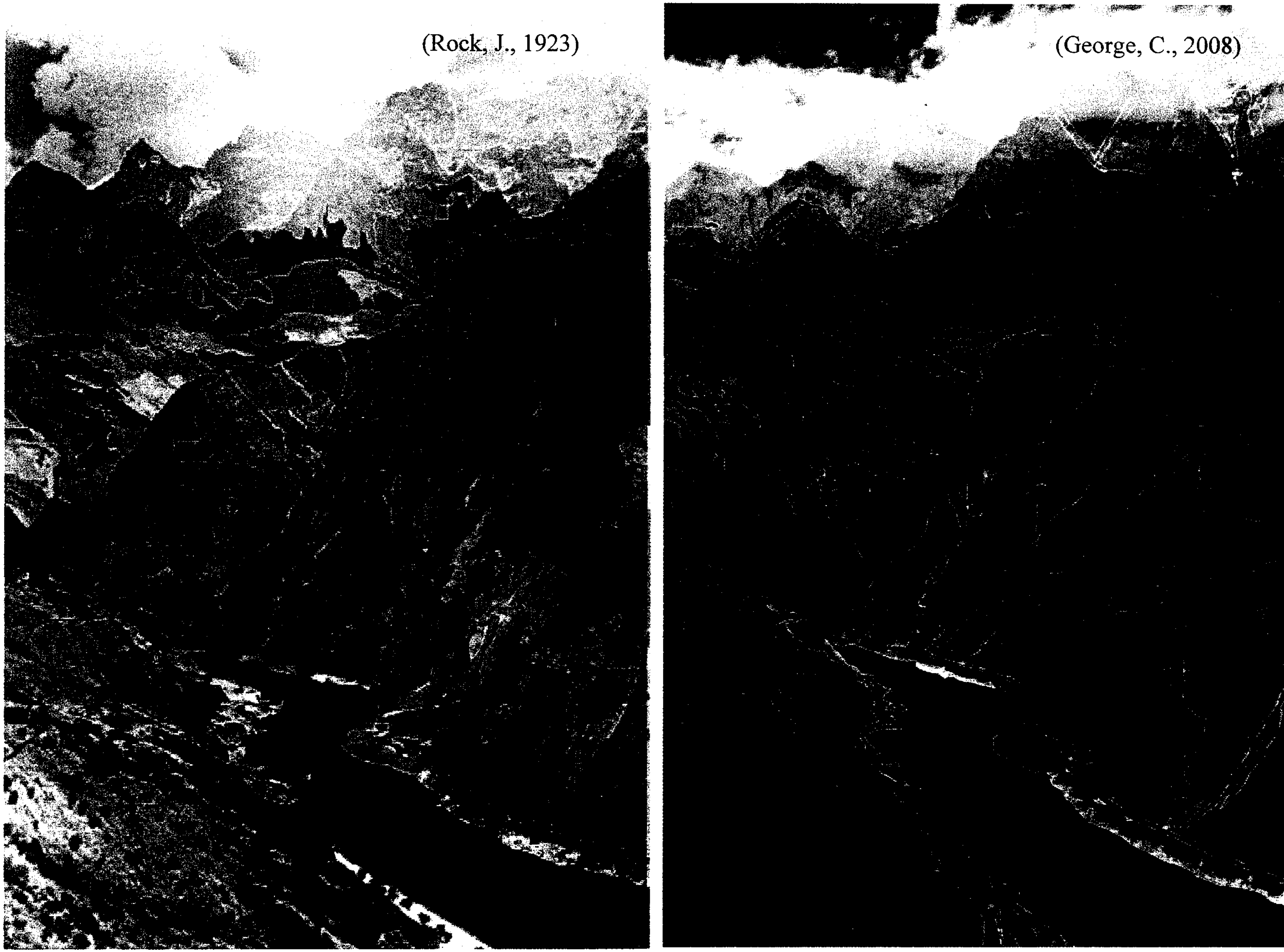
Table 4.3 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #19

Photo Set # 19 Landscape Characteristics	Presence/Absence Rock (1923)	George (2008)	Trend	Degrees of Change
[illegible]				
[illegible]	P	P	Increasing	Moderate
[illegible]	P	P	Increasing	Extensive
[illegible]	A	P	Increasing	Moderate
[illegible]	A	P	Increasing	Moderate
[illegible]	P	P	Stable	N/A
[illegible]	A	A	Stable	N/A
[illegible]	P	P	Increasing	Moderate
[illegible]	A	P	Increasing	Extensive
[illegible]				
[illegible]	P	P	Increasing	Extensive
[illegible]	P	P	Decreasing	Extensive
[illegible]	P	P	Decreasing	Moderate
[illegible]	P	P	Increasing	Slight
[illegible]	P	P	Stable	N/A
[illegible]	P	P	Stable	N/A
[illegible]				
[illegible]	P	P	Increasing	Moderate
[illegible]	P	P	Decreasing	Extensive
[illegible]	P	P	Decreasing	Extensive
[illegible]	P	P	Decreasing	Moderate
[illegible]	P	P	Decreasing	Extensive
[illegible]	P	P	Increasing	Extensive
[illegible]	P	P	Decreasing	Slight
[illegible]	P	A	Decreasing	Slight

that are exposed (highlighted in light brown) suggest some tectonic activity over the past several decades, specifically earthquakes. Unfortunately, this analysis is beyond the scope of this thesis.

For this next section, refer to **Figure 4.5** (p.84). Within both photographs, arid grasslands, shrublands, woodlands, *Pinus* forests, mixed forests, and subalpine coniferous forests are all present. Species of shrubs appear to be growing on the steep rock outcrops found in the center of the historic photograph (shown as light green spots over a light brown background). In the contemporary photograph, that sparse shrubland has disappeared, exposing the rock face underneath (shown in light brown). Also, in the

Figure 4.5 Photo Set #19 with an overlay of colour-coded landscape classifications.



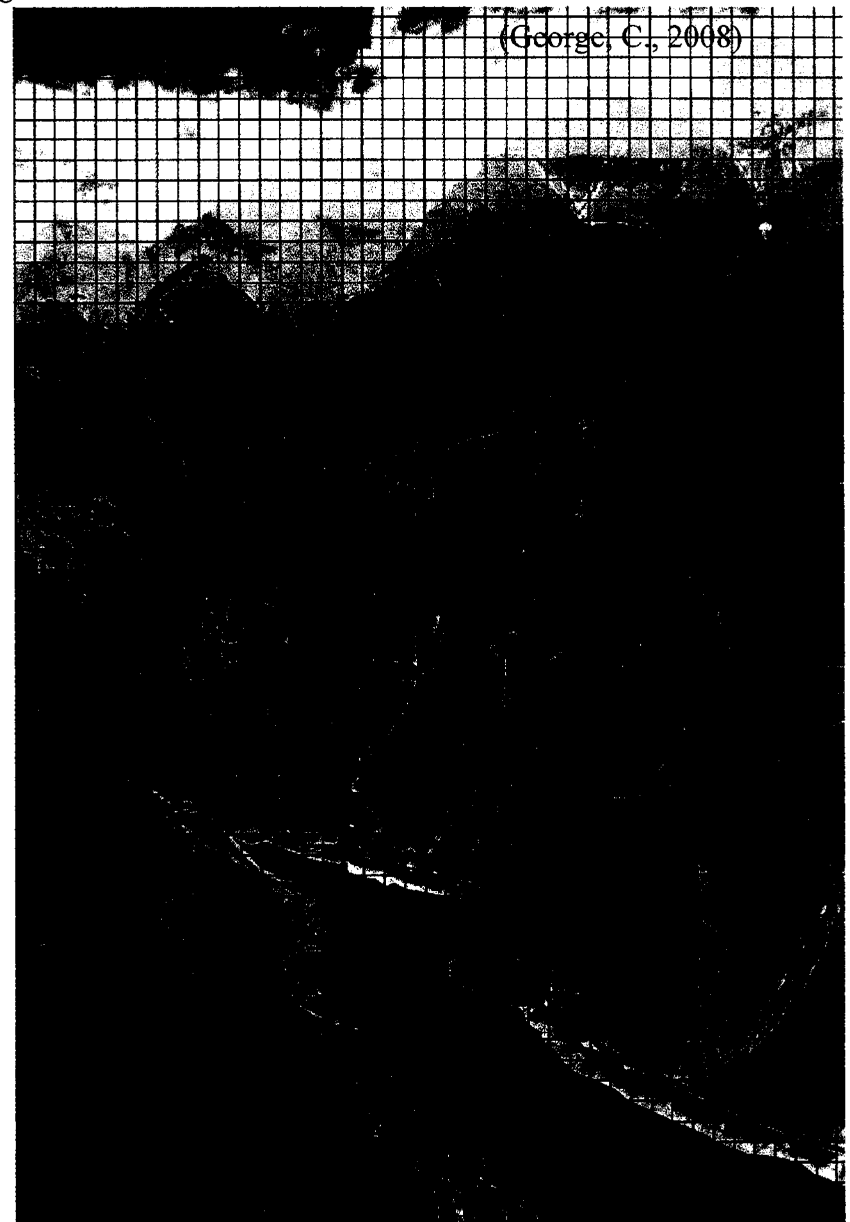
contemporary photograph, there are more tree species attempting to establish themselves on the slopes that are not as steep on that rock face (shown as dark green spots over light brown). In addition, where there looks to have been significant erosion in the historical photograph (shown in the center of the photograph as emerald green spots over dark brown), there is a dense mixed forest growing in the photograph taken in 2008 (shown in emerald green). Within the historic photograph, there appears to be an alpine shrubland in the upper-left quadrant of the photograph (shown in the upper middle section of the photograph in bright blue-green). The alpine environment seems relatively stable, but it is extremely difficult to tell based on this photo set.

As mentioned before, **Figure 4.5** (p.84) presents Photo Set #19 with colour-coded land use and vegetation classifications overlaid. As evident in this figure, there has been a notable increase in mixed forest, as well as arid grassland. There has been an extensive decrease in the area occupied by warm *Pinus* forest, *Pinus* savannah, woodlands and shrublands. The alpine environment, subalpine forest and subalpine meadow, appears to be decreasing slightly, but is relatively stable. For a summary of the qualitative landscape changes that are evident in Photo Set #19, consult **Table 4.3** (p.83).

4.4.1.2 Simple Grid Analysis of Photo Set #19

Using Simple Grid Analysis, I was able to quantify the changes that I identified through my qualitative analysis (refer to **Figure 4.6.**, page 86). For example, it was evident through my qualitative analysis that the area occupied by settlement had increased within the landscape area shown in Photo Set #19. Using Simple Grid Analysis, I was able to

Figure 4.6 Photo Set #19 with colour-coded landscape classifications and a grid overlaid.



quantify the area occupied with reference to the photo area. For Photo Set #19, the area occupied by settlement increased from occupying 2 grid squares (0.12% of the photo area) to occupying 7 grid squares (0.42% of the photo area).

The transportation infrastructure within the photo area increased almost 3-fold, occupying 9 grid squares (0.53% of photo area) in the historical photograph, to occupying 25 grid squares (1.50% of photo area) in the photograph taken in 2008. Although there was no agricultural land in the early 1900s, there was land occupied by agricultural lands in 2008 totaling 9 grid squares (0.54% of photo area).

Landscape Features showed notable changes. The exposed stable geomorphology increased from occupying 8.58% of the photo area in the historical photograph to occupying over 17% of the photo area in 2008. Mass wasting showed the opposite trend, decreasing from 6.27% of the photo area in the historical photograph to 1.56% in 2008. Also, the amount of glaciers and snow observed in the photograph showed considerable decline from 3.61% of the area occupied by the photograph, to 2.00%. The area occupied by fluvial hydrology showed the opposite trend, increasing from 8.94% to 10.05%.

Considerable changes occurred regarding the area occupied by vegetation communities. While arid grasslands increased from occupying 19.94% of the photo area in the historical photograph to occupying 27.27% in 2008, arid shrubland, woodlands and warm *Pinus* forest decreased, from 15.92% to 7.00%, 10.65% to 7.00%, and 8.52% to 3.89%, respectively. *Pinus* savannah disappeared entirely. Where the area occupied by mixed forest has increased 3-fold, the subalpine environment appears to have decreased. A summary of the above information can be found in **Table 4.4** (p.88).

Table 4.4 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #19

Photo Set # 19- Simple	Rock (1923)		George (2008)	
	Number	Percent	Number	Percent
[illegible]				
[illegible]	2	0.12	7	0.42
[illegible]	9	0.53	25	1.50
[illegible]	0	0.00	9	0.54
[illegible]	22	1.30	36	2.15
[illegible]				
[illegible]	145	8.58	286.5	17.13
[illegible]	106	6.27	26	1.56
[illegible]	61	3.61	20	1.20
[illegible]	151	8.94	168	10.05
[illegible]	15	0.89	15	0.90
[illegible]				
[illegible]	337	19.94	456	27.27
[illegible]	269	15.92	117	7.00
[illegible]	75	4.44	0	0.00
[illegible]	180	10.65	117	7.00
[illegible]	144	8.52	65	3.89
[illegible]	75	4.44	257.5	15.40
[illegible]	88	5.21	67	4.01
[illegible]	11	0.65	0	0.00
[illegible]				

*The difference in the total number of squares in the photograph is due to any inaccuracies retaking the historical photograph.

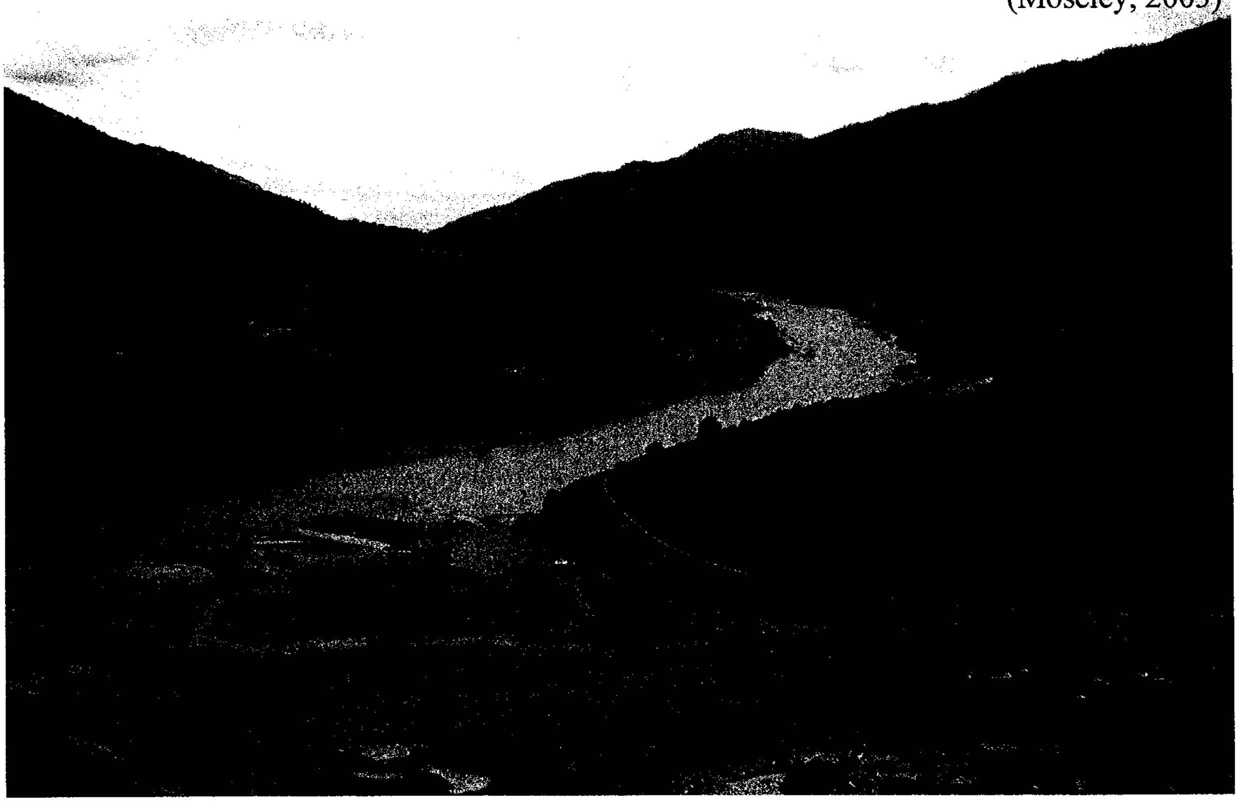
4.4.2 Photo Set #16

The photographs within this photo set were taken at the confluence of the Chung-Chiang Ho and Yangtze Rivers (27°10'25.1"°N, 100°03'55.7"°E). The picture is looking up the Yangtze River, with the Chung-Chiang Ho River flowing into it from the bottom right of the photograph. The unaltered photographs of this photo set are shown in **Figure 4.7** (p. 89-90).

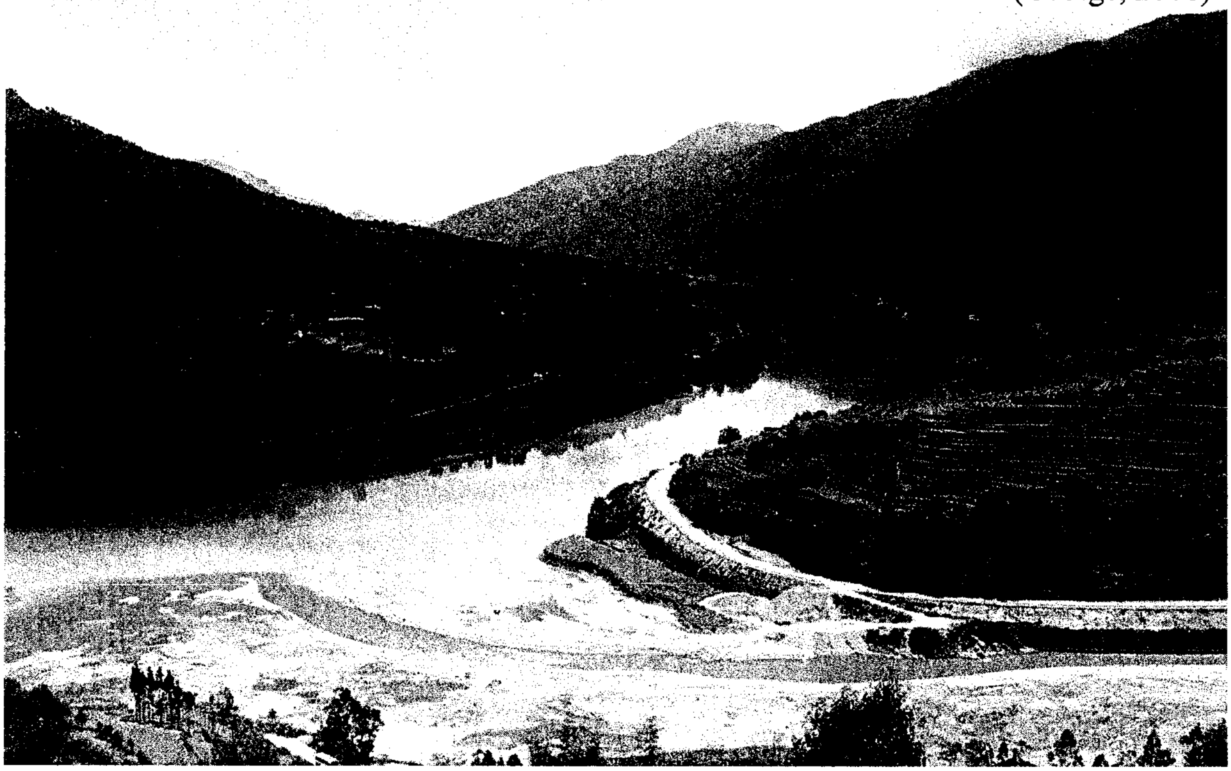
Figure 4.7 Photo Set #16, taken of the confluence of the Chung-Chiang Ho and Yangtze Rivers (27°10'25.1"°N, 100°03'55.7"°E)

(Rock, 1923)

(Moseley, 2003)



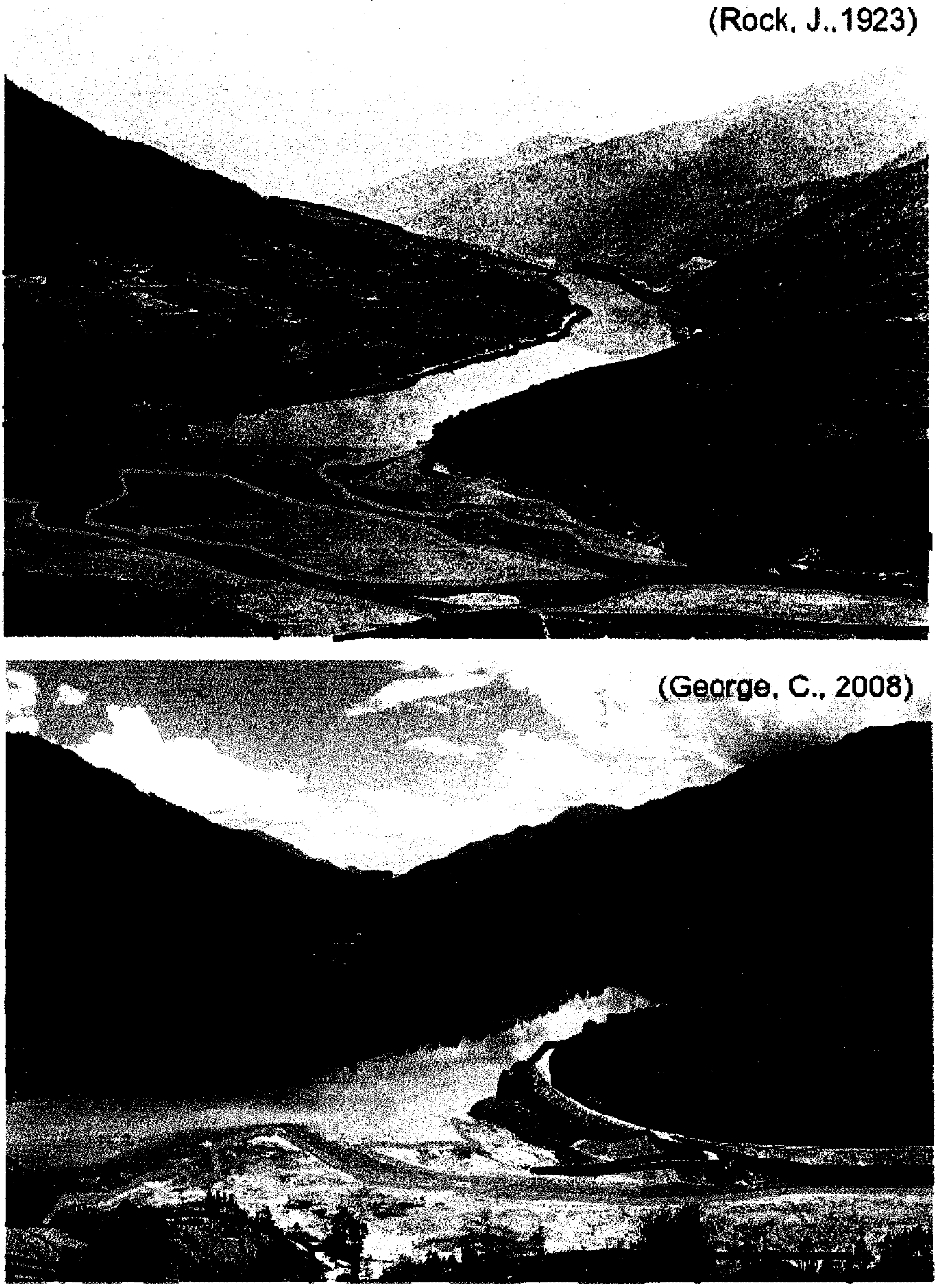
(George, 2008)



4.4.2.1 Qualitative Analysis of Photo Set #16

For this section, please refer to **Figure 4.8** (p.91). Settlement within this region has greatly increased. Where in Rock's historic photograph only eight houses are evident (outlined in magenta) there are over thirty houses apparent in the 2008 photograph. Despite the increase in population, the area occupied by agricultural lands has decreased and *Pinus* forests appear to have been planted on the abandoned agricultural lands to form forest plantations. There is also evident crop field abandonment in the background of the photograph along the right bank (noted in dark peach in Rock's photograph, but is absent in the 2008 photograph). There is also prominent pasture land bordering the agricultural lands on the upper right side of the historical photograph (shown in medium peach). This area has since become forested.

Figure 4.8 Photo Set #16 with overlay marking notable landscape changes.



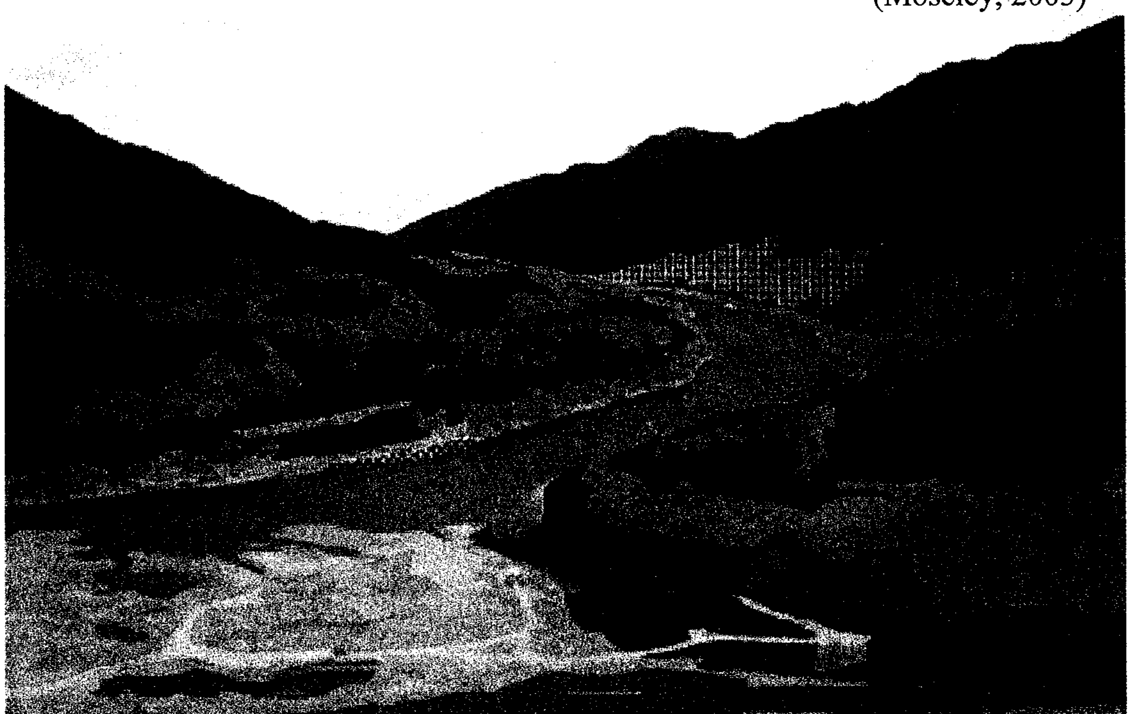
The change to transportation infrastructure has been extreme. In the historic photograph, there is evidence of dirt pathways along the river banks on both sides of the river (shown in purple). By 2008, there are paved roadways running along the Yangtze River on both banks, as well as secondary roadways branching off of these main roads and leading into the settlements. Rock cuts had to be done to implement the new road infrastructure. As well, road development on the steeper river slopes has resulted in significant erosion around the roadways. Both characteristics are evident on the right bank of the Yangtze River in Photo Set #16. Power lines run along the roadways bordering the Yangtze River in the more recent photograph (shown in red). Also evident in the newer photograph, clearings have been cut within the forest on the left bank to allow for a hydro line to pass through (evident in the middle of the left side of the 2008 photograph, shown in lighter green in **Figure 4.9**, p.93-94). This has been done since Moseley took his photographs in 2003. This suggests very recent development of hydro infrastructure in the area.

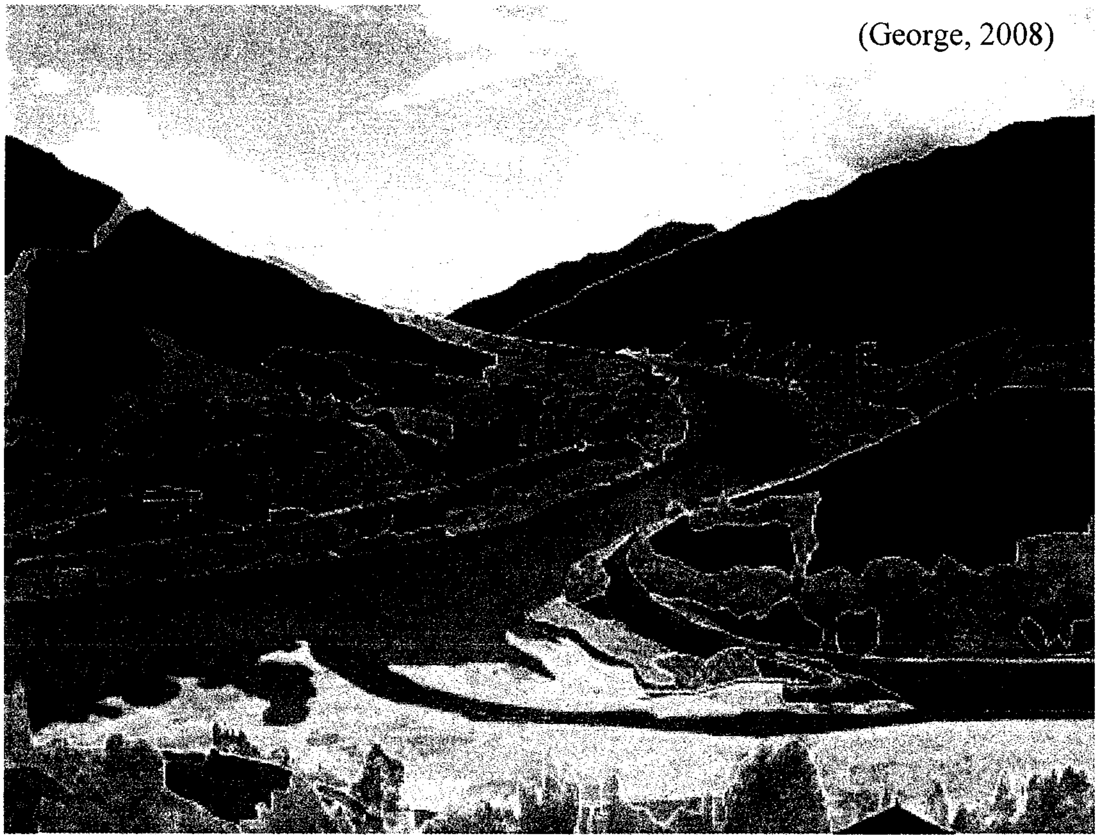
There is evidence of riverbank erosion in the historical photograph (shown in dark brown in Rock's photograph in **Figure 4.9**). This has since been mitigated by the appearance of riverbank vegetation, specifically *Salix* species and species of *Juglans* (shown in green and pink stripes in the recent photographs in **Figure 4.9**). The water levels in both photographs appear to be extremely low, exposing significant fluvial sediment (shown in gold). Mining of the confluence is apparent in Moseley's photograph. A dam upriver on the Chung-Chiang Ho River regulates the water flow into this confluence and allows for the extraction of fluvial sediments. In Moseley`s photograph, there is a gravel truck present within the confluence. There is also a road leading down into the confluence in both recent photographs, suggesting continuous mineral extraction.

Figure 4.9 Photo Set #16 with colour-coded landscape classifications overlaid.

(Rock, 1923)

(Moseley, 2003)





(George, 2008)

The confluence is surrounded by warm *Pinus* forest in all photographs. The dominant species is *Pinus densata*. Within the agricultural lands, deciduous trees have grown, apparent in the recent photographs. It appears that there has been some recent deforestation in the background of the photograph, along the right bank of the Yangtze River. It appears to be woodland or *Pinus* savannah in the recent photographs. For a summarized account of the qualitative information gained through the analysis of this photo set, consult **Table 4.5** (p.95).

4.4.2.2 Simple Grid Analysis of Photo Set #16

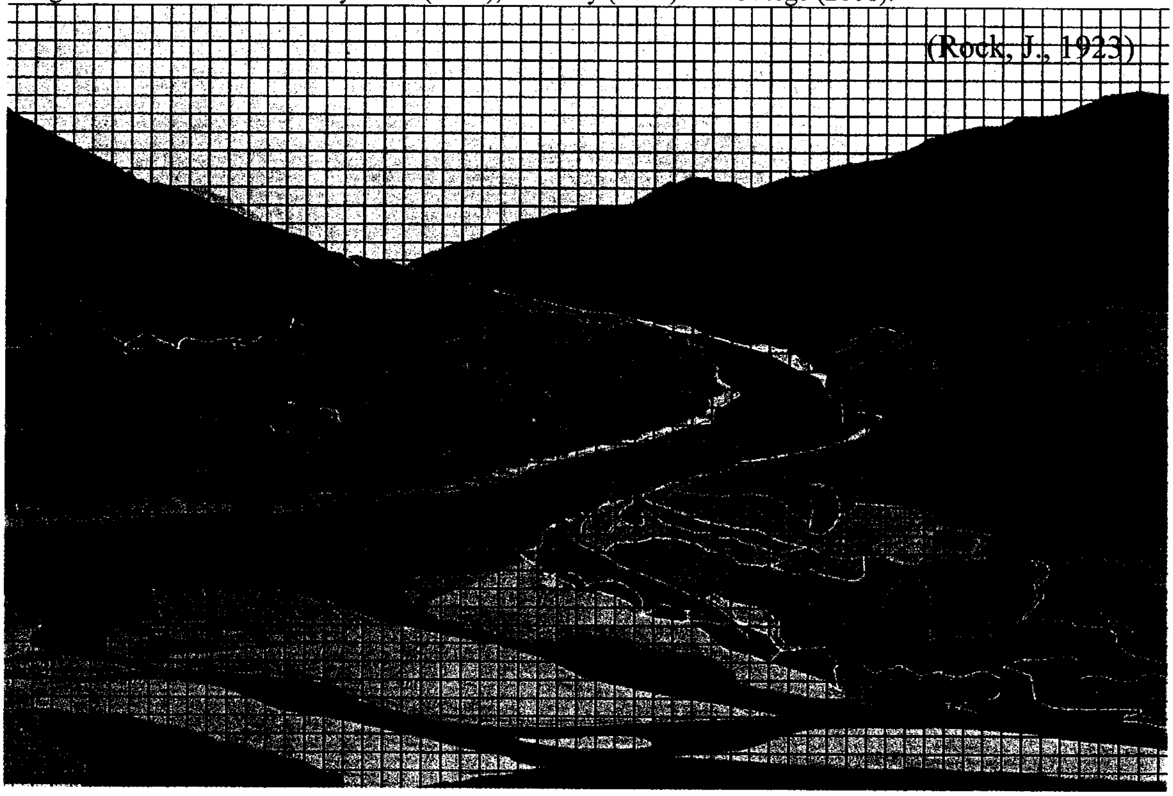
For photos showing the Simple Grid Analysis of Photo Set #16, please consult **Figure 4.10** (p.96-97). As evident in **Figure 4.10**, the area occupied by settlement has

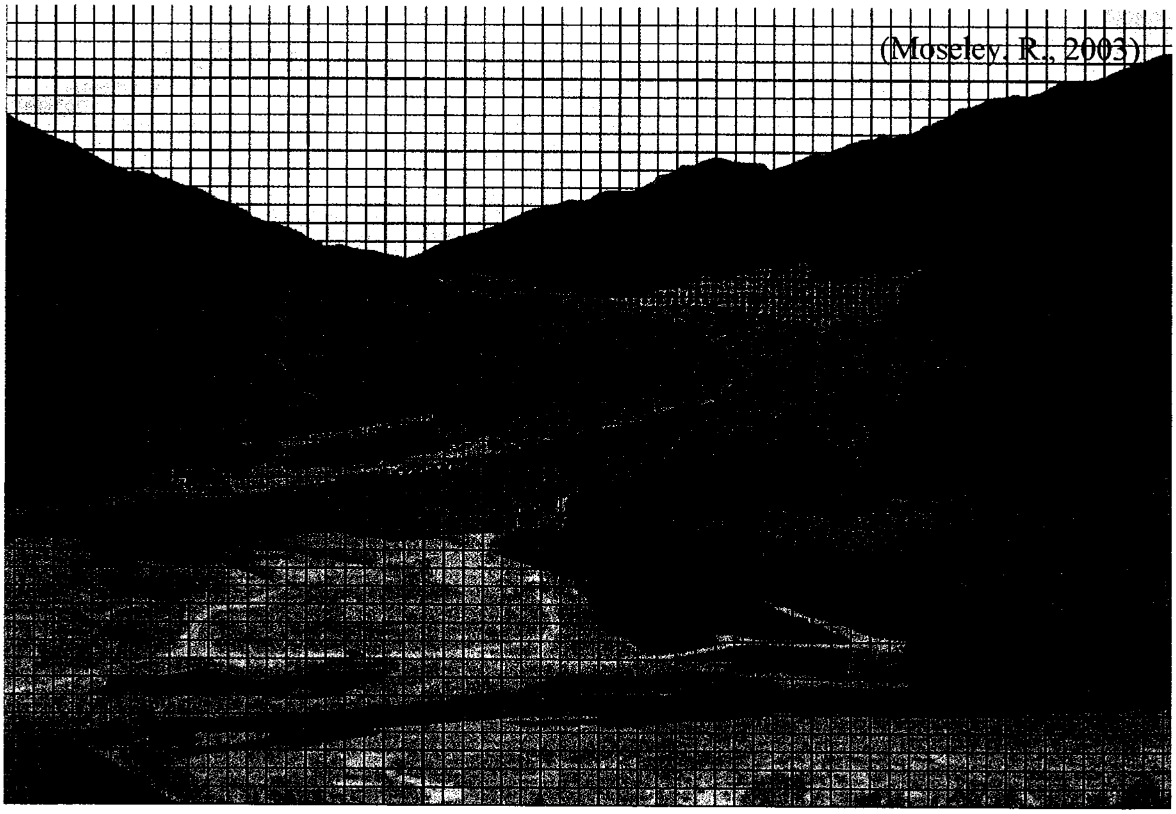
Table 4.5 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #16.

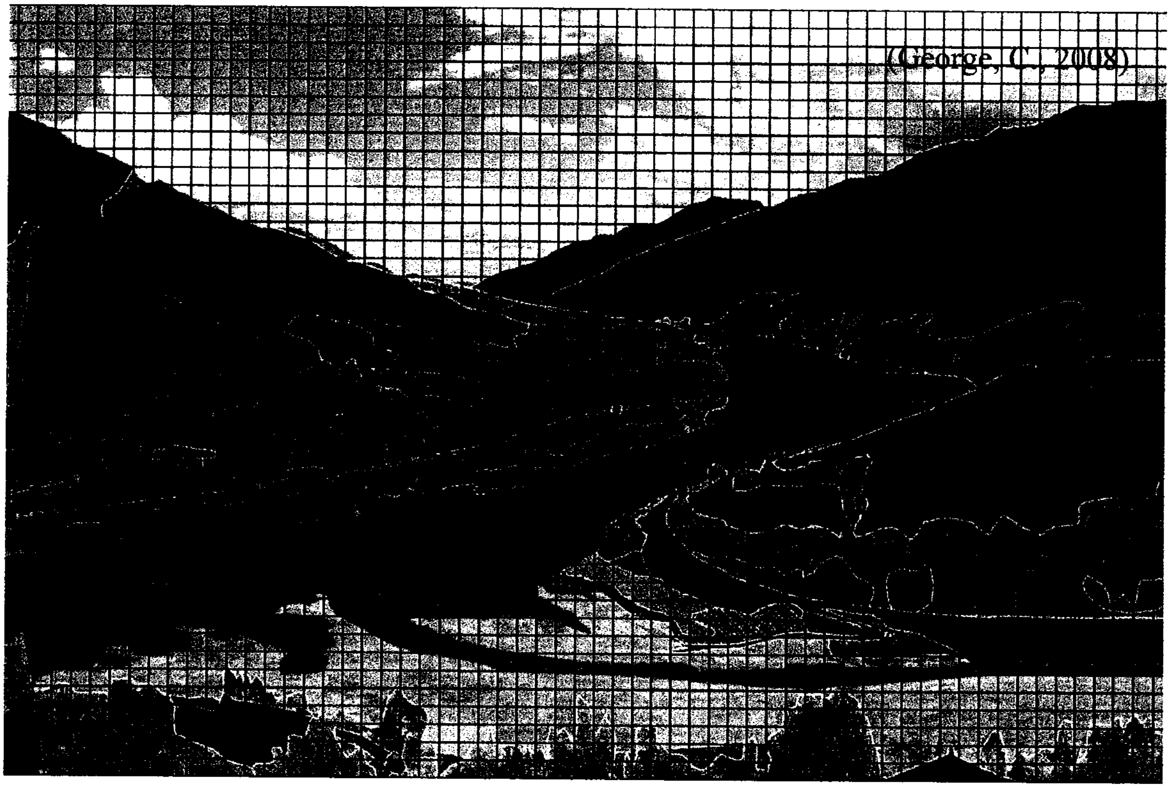
Photo Set # 16 Landscape Characteristics	Presence/Absence Rock (1923)	Moseley (2003)	George (2008)	Trend	Degrees of Change
[illegible]	P	P	P	Increasing	Moderate
[illegible]	P	P	P	Increasing	Extensive
[illegible]	A	P	P	Increasing	Slight
[illegible]	P	P	P	Decreasing	Moderate
[illegible]	P	A	A	Decreasing	Slight
[illegible]	P	P	P	Increasing	Moderate
[illegible]	A	P	P	Increasing	Moderate
[illegible]	P	A	P	Stable	N/A
[illegible]	P	P	P	Decreasing	Slight
[illegible]	P	P	P	Increasing	Slight
[illegible]	P	A	A	Decreasing	Moderate
[illegible]	A	A	A	Stable	N/A
[illegible]	P	P	P	Decreasing	Slight
[illegible]	P	P	P	Increasing	Slight
[illegible]	A	A	A	Stable	N/A
[illegible]	A	P	P	Increasing	Slight
[illegible]	A	P	P	Increasing	Slight
[illegible]	A	P	P	Increasing	Slight
[illegible]	P	A	A	Decreasing	Slight
[illegible]	P	P	P	Increasing	Slight
[illegible]	A	A	A	Stable	N/A
[illegible]	A	A	A	Stable	N/A
[illegible]	A	A	A	Stable	N/A
[illegible]	A	A	A	Stable	N/A
[illegible]	A	A	A	Stable	N/A
[illegible]	A	A	A	Stable	N/A
[illegible]	A	A	A	Stable	N/A

increased from 0.32% of the photo area to 1.44% of the photo area (shown in magenta). Similarly, the area occupied by transportation infrastructure (shown in purple) has also increased. In the historical photograph, transportation infrastructure only occupied 0.11% of the photo area. In Moseley's photograph, transportation infrastructure peaked at its highest value of 6.27% of the photo area. The area occupied by transportation

Figure 4.10 Photo Set #16 with a simple grid overlaid. Landscape characteristics are highlighted according to legend. Photos were taken by Rock (1923), Moseley (2003) and George (2008).







infrastructure then declined to 2.76% of the photo area, as the roadways present within the confluence in the 2003 photograph have since been destroyed. While in the historical photograph there was no industrial infrastructure present (shown in red), the recent photographs each note industrial infrastructure occupying three and five grid squares, respectively. This is equal to 0.27% of the photo area in Moseley's photograph in 2003 and 0.28% of the photo area in my own photograph.

Agricultural lands have decreased notably, from occupying 26.09% to occupying only 12.65% in Moseley's photograph, and 15.41% in 2008 (shown in dark peach). The grazing pastures present in the historical photograph have disappeared from this photo area (shown in medium peach). Where pasture lands occupied 0.96% of the photo area in the historical photograph, there was no grazing land apparent in either of the recent photographs. Forest plantations are apparent in all of the photographs, all occupying fewer than seven percent of the photo area (shown in stripes of light peach and dark forest green). The human impacted vegetation has increased over the past century (shown in stripes of light peach and emerald green). Only 5.55% of the photo area was occupied by human impacted vegetation in the historical photograph, but, in the recent photographs, there is 15.71% and 17.74% of the photo area occupied by human impacted vegetation in Moseley's photograph and my own photograph, respectively. Also, as mentioned in the qualitative analysis of this photograph, there are notable reclaimed agricultural lands present in each photograph of this photo set. The area occupied by abandoned agricultural lands is fairly consistent, values being slightly higher in the historic photograph (0.44% of photo area).

Whereas natural events of mass wasting are not seen within any of the photographs in this photo set, the appearance of human-induced erosion has increased, from not appearing in the 1923 photograph, to occupying 0.39% of the photo area in the 2003 photograph (shown in stripes of dark brown and purple).

The photo area occupied by fluvial hydrology has shown only slight variation. Fluvial hydrology occupies 20.76% of the photo area in the historic photograph, 12.65% of Moseley's, and 20.72% of my own (shown in blue). The photo area occupied by fluvial geomorphology reveals the opposite trend, occupying 16.70% of the photo area in the historical photograph, 22.42% in Moseley's photograph, and 12.93% of the photograph taken in 2008 (shown in gold). The combination of both the river hydrology and geomorphology reveals a notable trend. The total has continually decreased from 37.46% in Rock's photograph, to 35.07% in Moseley's photograph, to 33.65% in the photograph taken as part of this study. This shows that the floodplain has decreased in this area, suggesting that water levels have decreased.

Overall, there are very few vegetation communities represented within this landscape photograph. The dominant vegetation community, the warm *Pinus* forest, occupies approximately the same amount of photo area in every photograph, 23.53% in Rock's photograph, 21.09% in Moseley's photograph, and 22.92% in my own photograph (shown in dark forest green). A notable vegetation change is the transition and expansion of woodland vegetation in the historic photograph, occupying 1.76% of the photo area, into arid shrubland (2.55%), and *Pinus* savannah (1.05%) by 2008. For a detailed account of the number of grid squares and percentages of photo area occupied by each vegetation community and landscape classification for Photo Set #16, consult **Table 4.6**.

Table 4.6 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #16

Photo Set # 16- Simple	**Rock (1923)**		**Moseley (2003)**		**George (2008)**	
	Number	Percent	Number	Percent	Number	Percent
[illegible]	6	0.32	16	0.89	26	1.44
[illegible]	2	0.11	113	6.27	50	2.76
[illegible]	0	0.00	3	0.17	5	0.28
[illegible]	489	26.09	288	12.65	279	15.41
[illegible]	18	0.96	0	0.00	0	0.00
[illegible]	10	0.53	0	0.00	12	0.66
[illegible]	104	5.55	283	15.71	321	17.74
[illegible]	0	0.00	7	0.39	7	0.39
[illegible]	47	2.51	30	1.67	29	1.60
[illegible]	0	0.00	8	0.44	8	0.44
Rock	22	1.17	42	2.33	20	1.11
[illegible]	389	20.76	228	12.65	375	20.72
[illegible]	313	16.70	404	22.42	234	12.93
[illegible]	0	0.00	0	0.00	0	0.00
Arid Shrubland	0	0.00	46	2.55	0	0.00
Pinus Savannah	0	0.00	0	0.00	19	1.05
Woodlands	33	1.76	14	0.78	10	0.56
Warm *Pinus* Forest	441	23.53	380	21.09	415	22.93

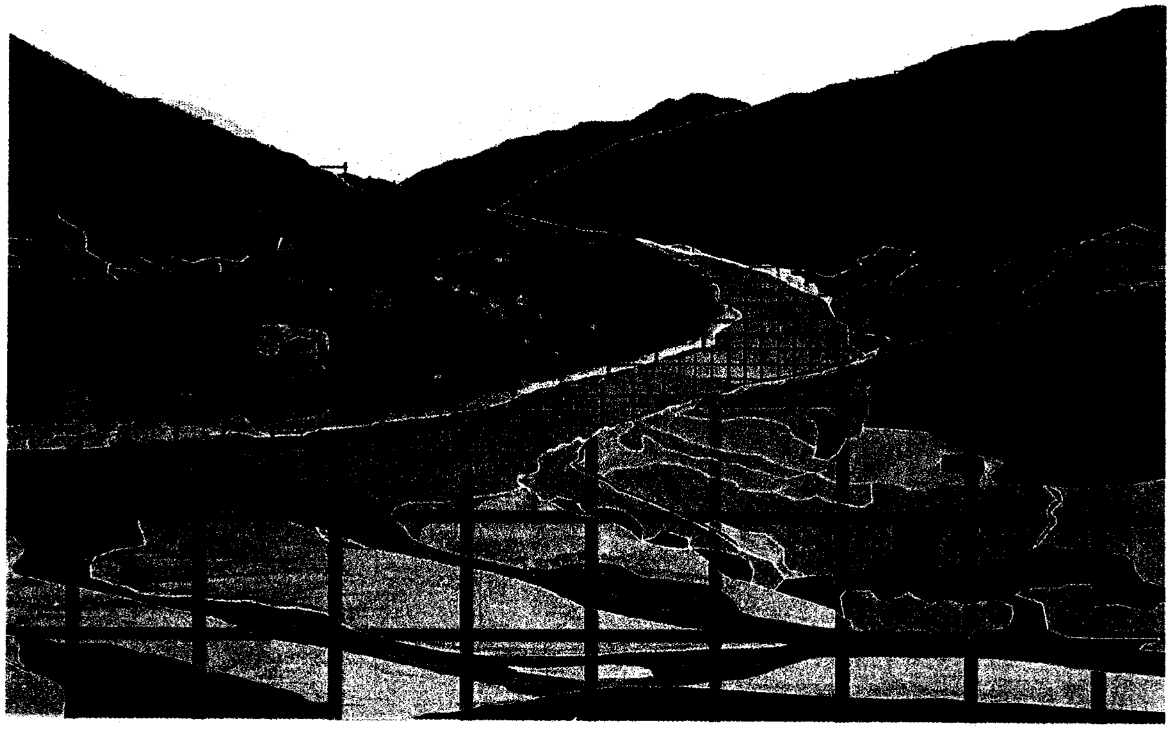
4.4.2.3 Scaled Grid Analysis of Photo Set #16

As discussed previously, Scaled Grid Analysis allows for a quantitative assessment of the area occupied by each landscape feature within each photograph. Rather than determining the area occupied by each landscape classification on the photograph itself, Scaled Grid Analysis measures the area occupied by different vegetation communities and land use classifications on different landscape planes that are depicted on the photograph. As a result, the number of grid squares occupied by vegetation communities, as well as the percentage of each landscape characteristic with respect to the total photo area is notably different. I will mention a few examples for Photo Set #16.

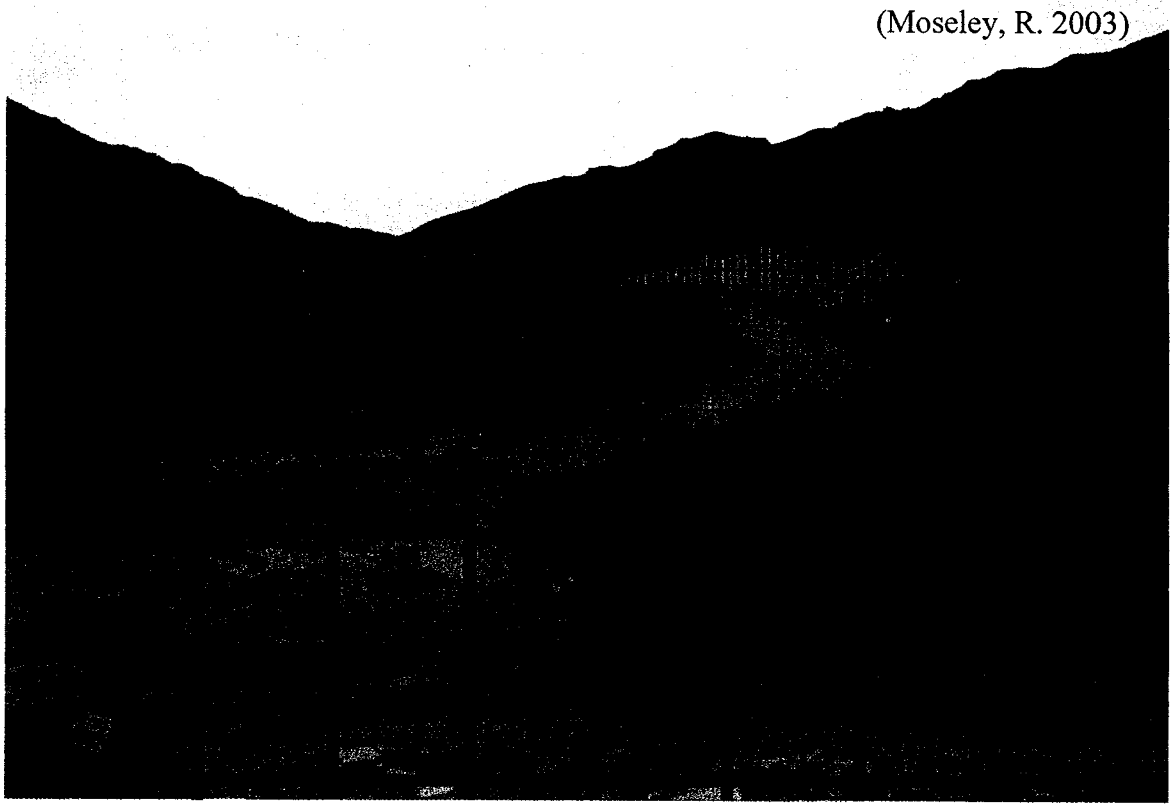
In Photo Set #16, Simple Grid Analysis revealed that the area occupied by warm *Pinus* forest decreased from 30.46% of the photo area in the historical photograph to 20.32% in Moseley's photograph, to 25.29% in 2008. Scaled Grid Analysis also noted a decrease in the area occupied by warm *Pinus* forest; however, the change was not as dramatic. Also, using Scaled Grid Analysis, the warm *Pinus* forest occupied a much larger area of the landscape. In the historical photograph, warm *Pinus* forest occupied 87.20% of the landscape, 86.36% in 2003, and 85.01% in 2008. This shows that the amount of warm *Pinus* forest has stayed relatively the same throughout the past century. To contrast, the percentages generated for the area occupied for agricultural lands using Simple Grid Analysis were much larger than those generated used Scaled Grid Analysis. Simple Grid Analysis showed a decrease in agricultural lands from 20.71% in the historical photograph, to 15.61% in 2003, to 16.14% in 2008. Scaled Grid Analysis also noted a decrease; however, Scaled Grid Analysis revealed the historical value for the area occupied by

Figure 4.11 Photo Set #16 with scaled grids overlaid that are calibrated to fit the landscape. Also, the colour-coded distributions of vegetation communities have been added.

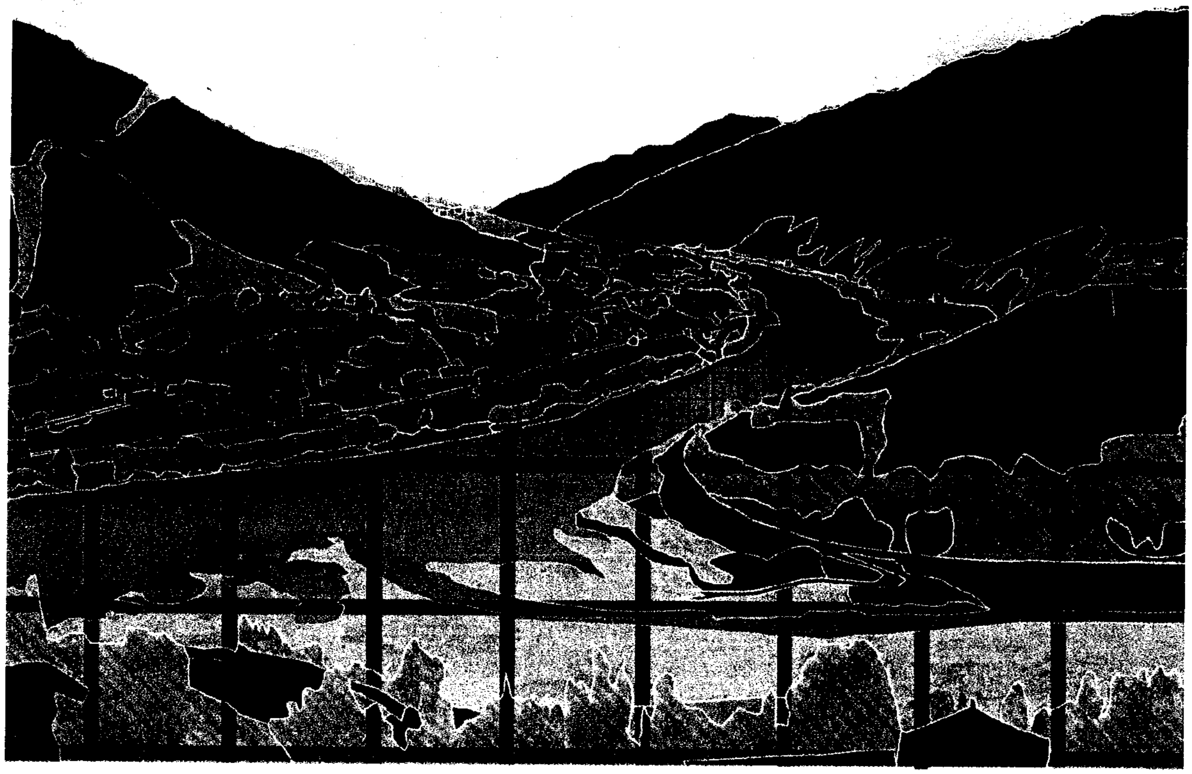
(Rock, J. 1923)



(Moseley, R. 2003)



(George, C., 2008)



agricultural lands to be only 4.46% of the total landscape, 2.40% in 2003, and 2.34% in 2008. In general, those landscape classifications showing human land use, settlement, transportation infrastructure, industrial infrastructure, agricultural lands, human-impacted vegetation, are all overrepresented using Simple Grid Analysis, as those landscape features are in the foreground of the photograph. In Scaled Grid Analysis, this reality is accounted for. To contrast, the vegetation communities are commonly underrepresented using Simple Grid Analysis. For values of the number of grid squares and percentage of landscape area occupied in Photo Set #16 for each landscape classification using Scaled Grid Analysis, consult **Table 4.7** (p.103).

Table 4.7 This table shows the results of the scaled grid analysis of Photo Set #16. The first column shows the number of squares occupied by each landscape classification in each photograph (Rock, Moseley, George). The number values are calculated into percentages of the total number of squares in each photograph.

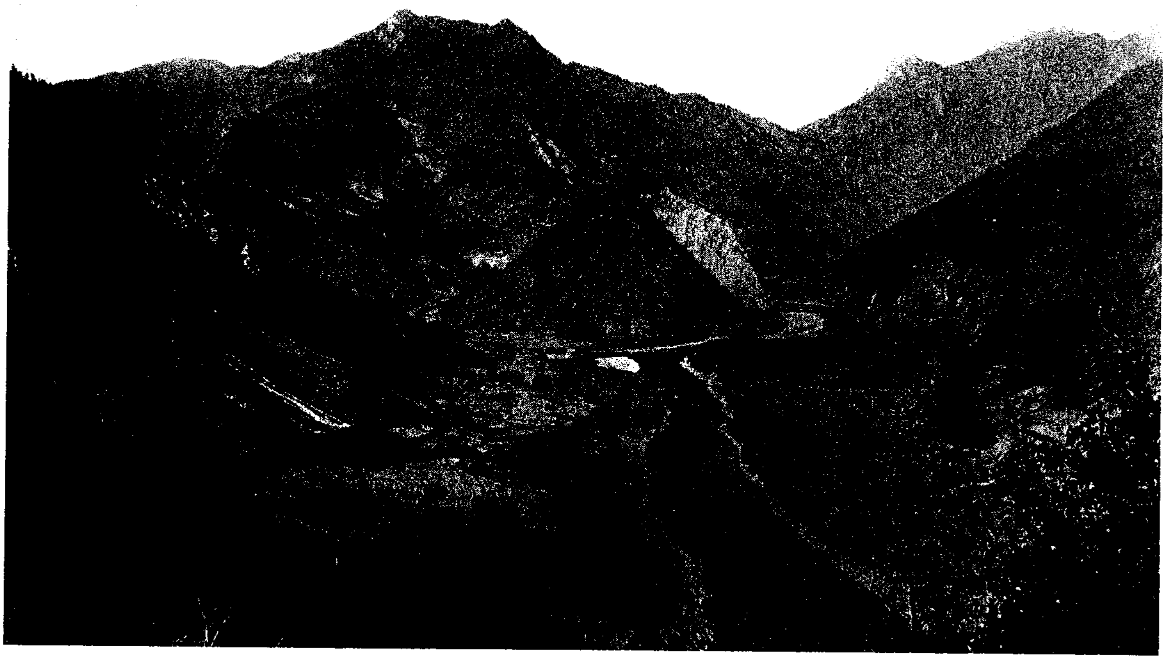
Photo Set # 16- Scaled	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
[illegible]	1	0.06	2	0.11	3	0.21
[illegible]	1	0.06	5	0.29	4	0.28
[illegible]	0	0.00	1	0.06	1	0.07
[illegible]	76	4.46	42	2.40	33	2.34
[illegible]	5	0.29	0	0.00	0	0.00
[illegible]	6	0.35	5	0.29	5	0.34
[illegible]	9	0.53	36	2.06	39	2.77
[illegible]	0	0.00	3	0.17	2	0.14
[illegible]	2	0.12	0	0.00	0	0.00
[illegible]	1	0.06	4	0.23	4	0.28
[illegible]	0	0.00	2	0.11	1	0.07
[illegible]	3	0.18	0	0.00	0	0.00
[illegible]	83	4.87	80	4.57	89	4.32
[illegible]	20	1.17	15	0.86	8	0.57
[illegible]	0	0.00	3	0.17	3	0.21
[illegible]	0	0.00	8	0.46	9	0.64
[illegible]	11	0.65	33	1.88	10	0.71
[illegible]	0	0.00	0	0.00	0	0.00
[illegible]	1485	87.20	1513	86.36	1397	87.01

4.4.3 Photo Set #3

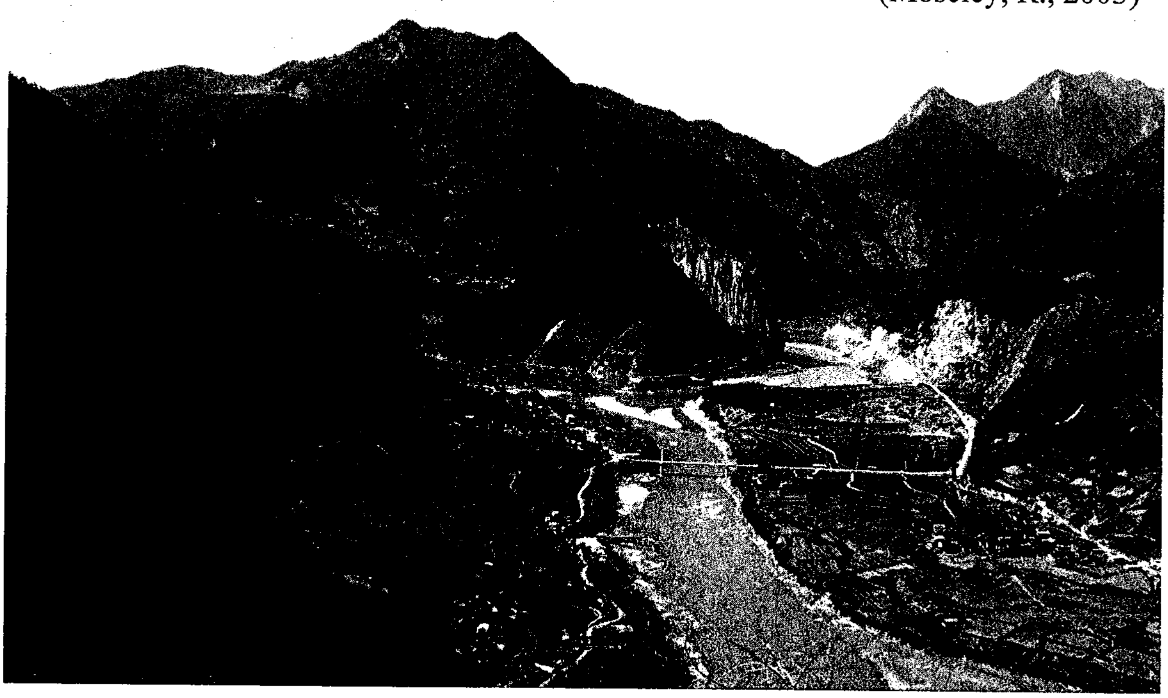
This photo set is taken of the Yangtze River at the borders of the Deqin County, Wexi/Lisu County and Shangri-la County (27°33"37.1" N-99.32.11.5" E, 2128 m). This photo set contains 3 photographs, the historical photograph provided by Rock (1923), Moseley's photograph, taken in 2003, and my own photograph, taken in 2008. Consult **Figure 4.12** on pages 104-105 for the unaltered photographs.

Figure 4.12 Photo Set #3, taken of the Yangtze River at the borders of Deqin County, Wexi/Lisu County and Shangri-la County (27°33'37.1"°N, 99°32'11.5"E, 2118 m).

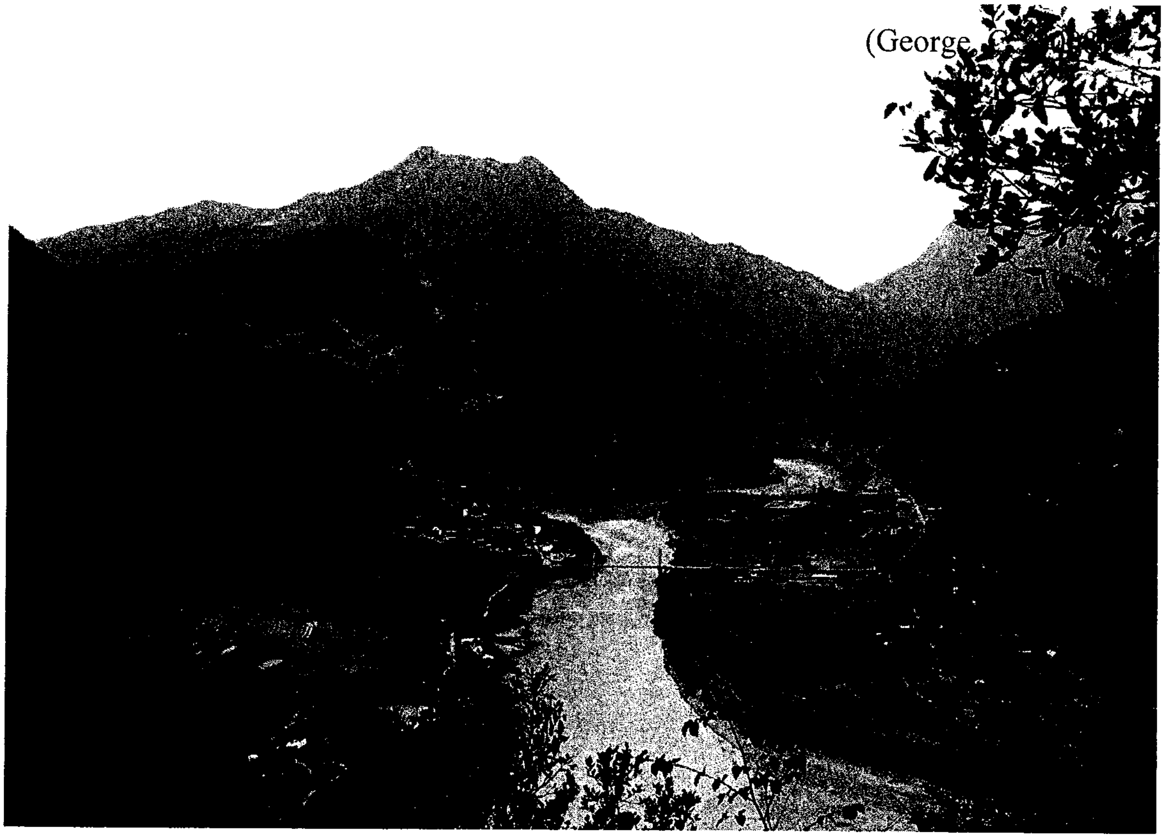
(Rock, J. 1923)



(Moseley, R., 2003)



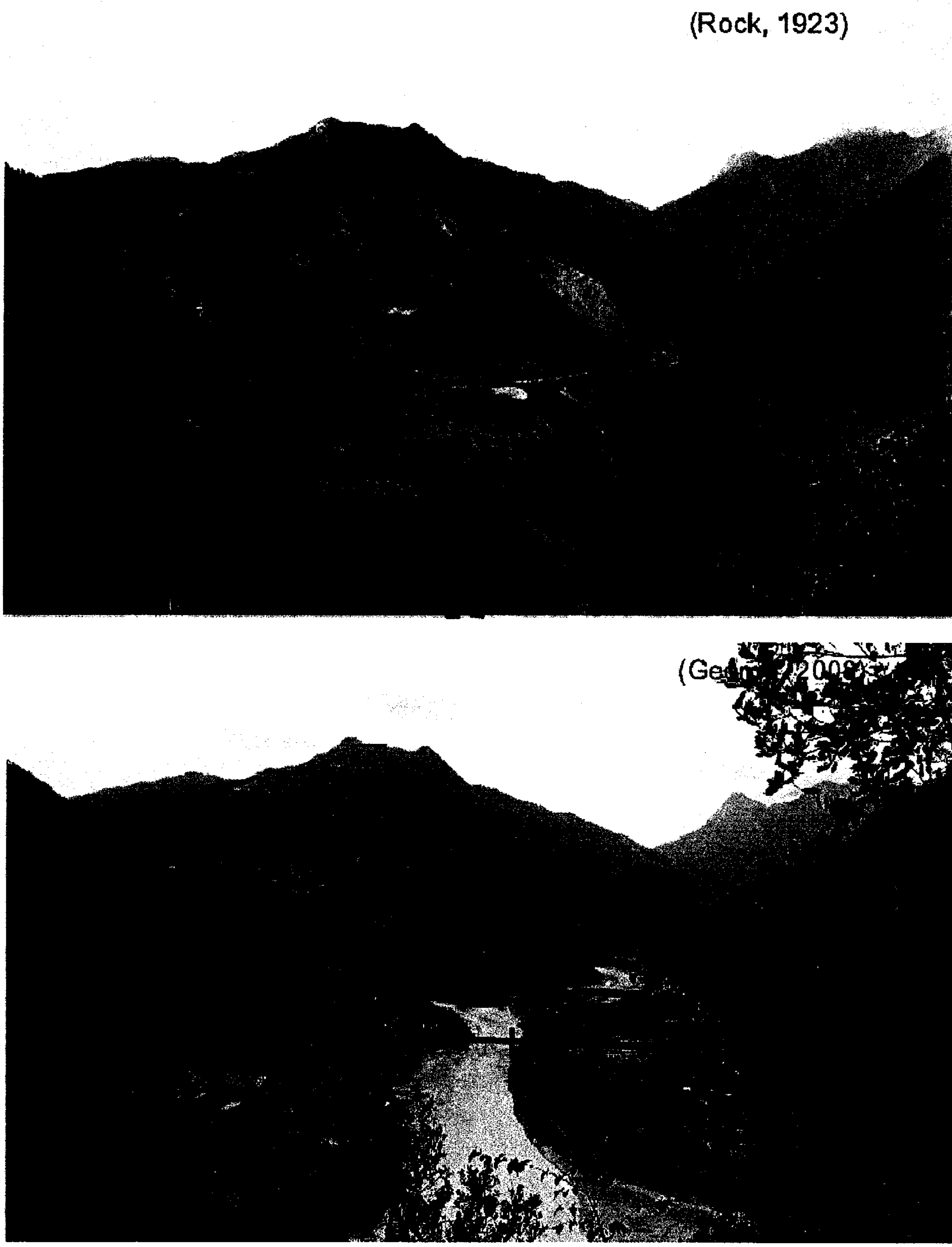
(George



4.4.3.1 Qualitative Analysis of Photo Set #3

When comparing the historic photograph in Photo Set #3 to the contemporary photographs, there have been several notable changes. The settlement in the photograph has increased in both size and density (settlement outlined in magenta in **Figure 4.13**). The number of buildings shown in the photo area has increased 10-fold. There are two temples evident in all of the photographs looking over the village. The first temple is located in the top left quadrant of each photograph at the top of the mountain. The second is located on the slope on the right side of the photograph. Both temples are highlighted in florescent pink. The agricultural lands surrounding the village have decreased over the past century within the valley (outlined in dark peach); however, there has been land cleared on the

Figure 4.13 Photo Set #3 with an overlay marking notable landscape changes.



lower slopes of the mountain in the background. This is likely pasture land (outlined in medium peach). Most of the area that was previously agricultural land is now occupied by deciduous forest (shown in **Figure 4.13** in striped emerald and light pink).

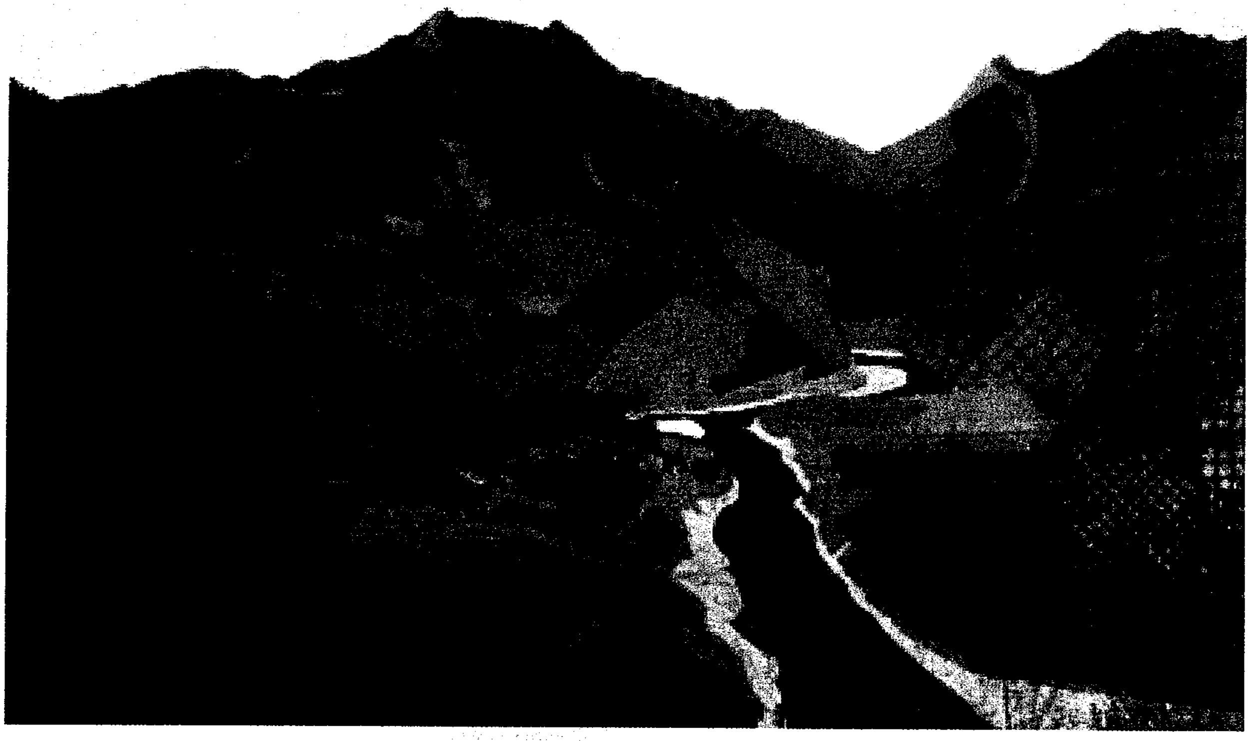
There are very few transportation routes evident in the historic photograph; a path leading to the temple on the right side of the photograph is the only evident transportation route. In the recent photographs, however, there are paved roadways running on both banks of each waterway (highlighted in purple). There is also a major bridge crossing the Yangtze River in the center of the photograph. Major mass wasting events caused by the implementation of transportation infrastructure are evident in both recent photographs along the right side of the river in the middle ground of the photograph (shown in dark brown and purple stripes in the 2008 photograph in **Figure 4.14**).

Hydro lines and towers are evident in the 2008 photograph. As well, there is a power generating station located in the center of my photograph (outlined in red). There are major power lines and larger towers leading away from the power station. This power infrastructure has been implemented since Moseley's photograph was taken in 2003 and has caused notable disturbance to the vegetation that had to be cut through for the power lines to be put up. The *Pinus* woodlands that were previously seen in the historical photograph have been degraded to sparse shrublands by 2008 (shown in the middle of the 2008 photograph as light green dots over light pink).

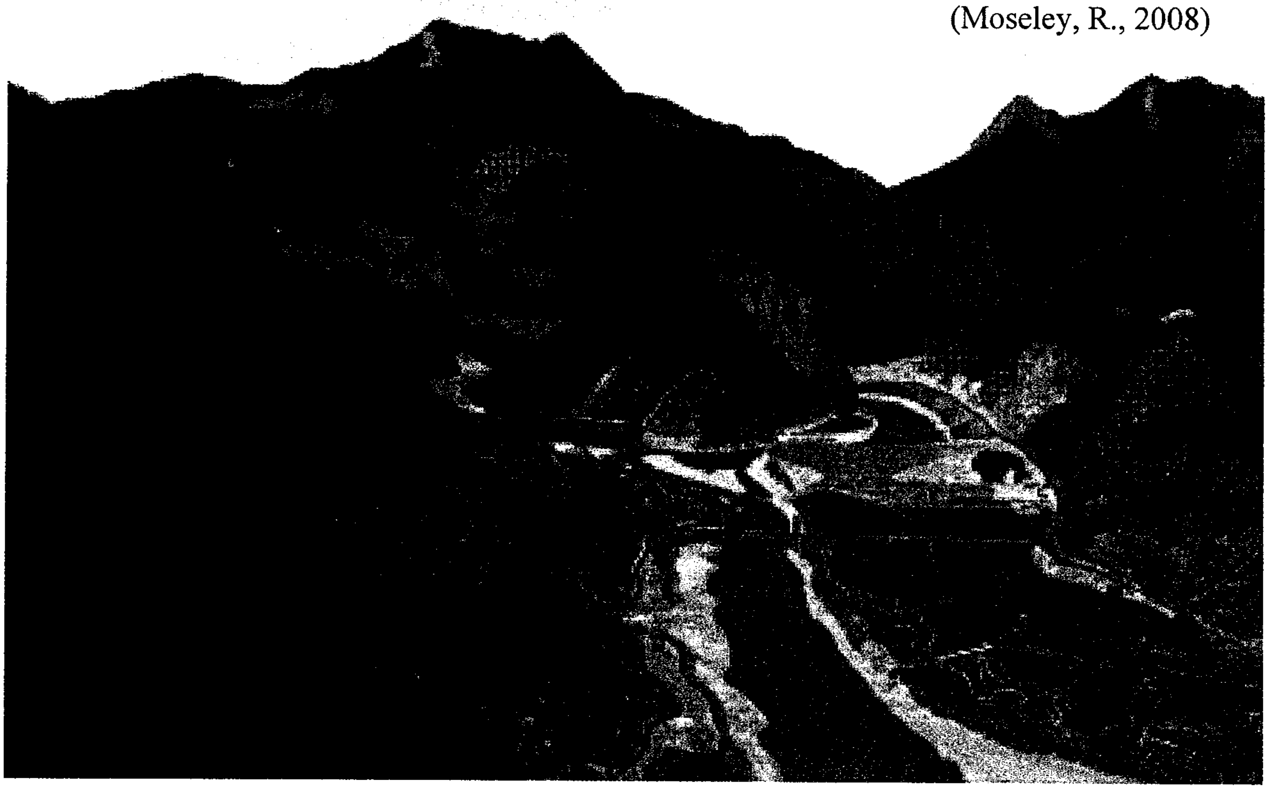
There are no significant changes to river hydrology or fluvial geomorphology evident within the photo set; however, there is evidence of seasonal variation in water level – the water levels are higher in my photograph that was taken in the summer than in

Figure 4.14 Photo Set #3 with colour-coded landscape classifications overlaid.

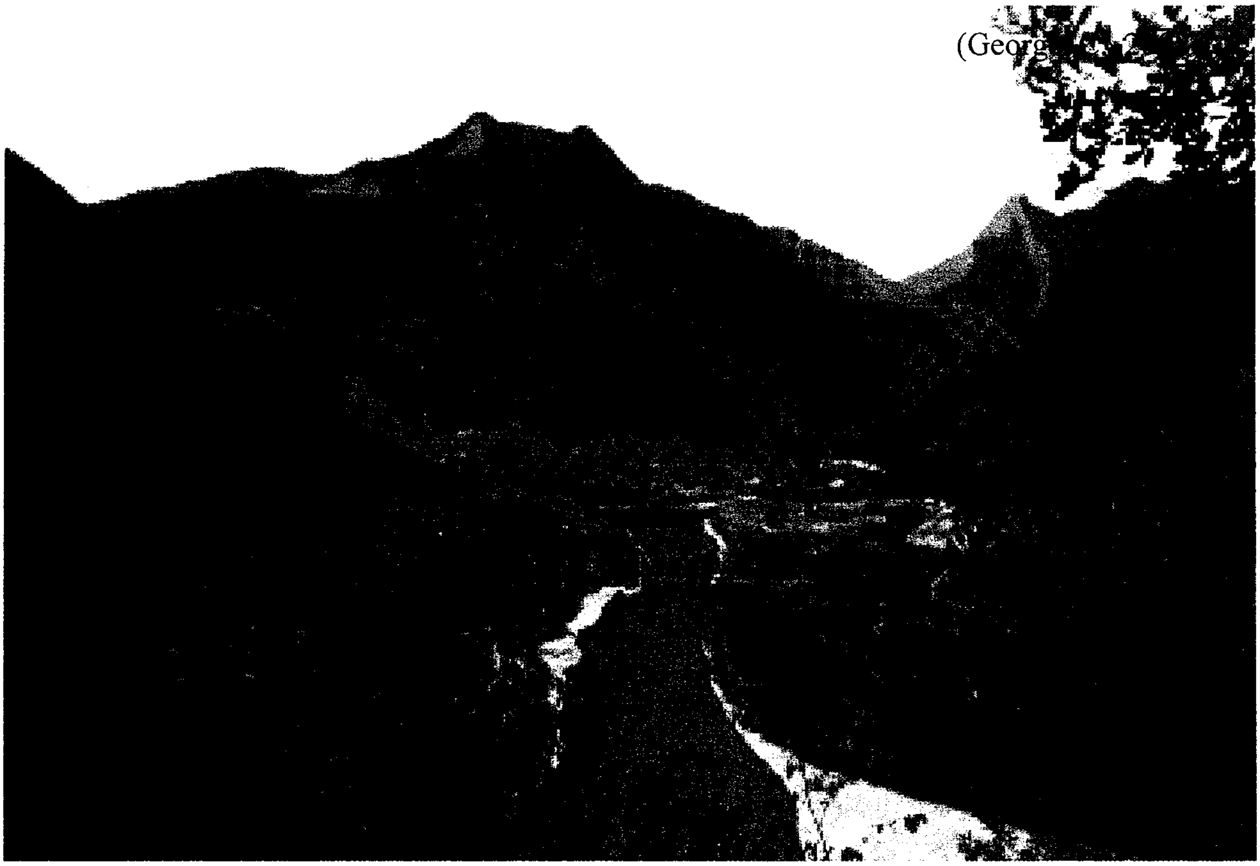
(Rock, J. 1923)



(Moseley, R., 2008)



(Ge



Rock and Moseley's photographs that were taken in the winter (shown in blue in **Figure 4.14**). The riverbank vegetation has increased significantly when comparing the historical photograph to the two more recent photographs. *Juglans* have been planted along the river to mitigate riverbank erosion (shown in striped light pink and emerald green in **Figure 4.14**).

Within the photographs in this photo set, the majority of forested areas appear to be warm *Pinus* forest (shown in dark forest green in **Figure 4.14**). Mixed forest is also present in the more sheltered, moister areas (shown in emerald green). In comparison to the historic photograph, the tree density has greatly increased in forested areas. The sparse *Pinus* woodlands present in Rock's photograph on the right slope have become warm *Pinus* forest and mixed forest. Selective felling could have been used during the early part of the twentieth century, resulting in lower density Pinus savannahs and woodlands. This could also be related to changes in temperature and precipitation patterns over the past century. The exposed geomorphology on the top right of the historical photograph, shown in brown, suggests deforestation practices. Further discussion on these topics will occur in Chapter 5. For a summary of the landscape changes found in Photo Set #3, consult **Table 4.8**.

Table 4.8 Qualitative analysis for Photo Set #3, including Presence/Absence Trends and Degrees of Change.

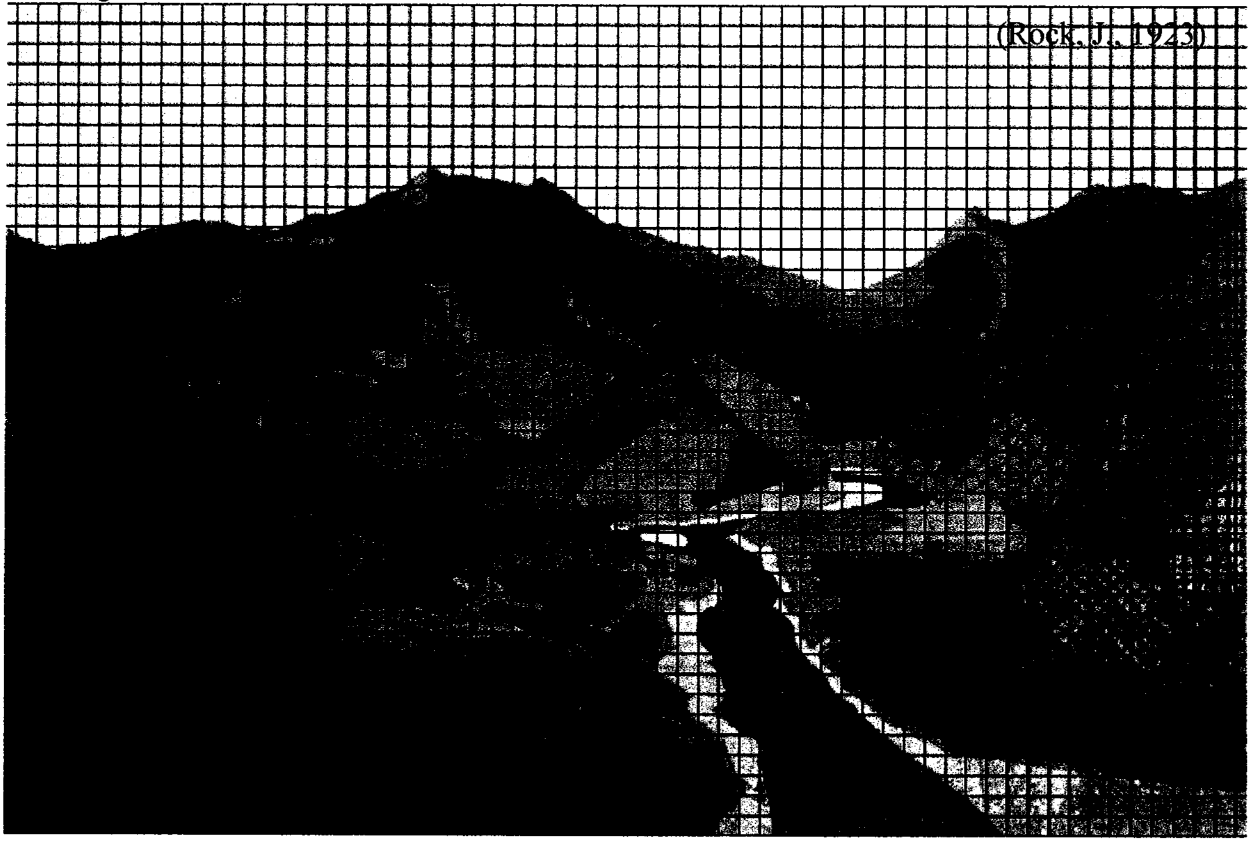
Photo Set # 3 Landscape Characteristics	Presence/Absence			Trend	Degrees of Change
	Rock (1923)	Moseley (2003)	George (2008)		
[illegible]					
[illegible]	P	P	P	Increasing	Moderate
[illegible]	A	P	P	Increasing	Moderate
[illegible]	A	P	P	Increasing	Moderate
[illegible]	P	P	P	Decreasing	Extensive
[illegible]	P	P	P	Decreasing	Slight
[illegible]	A	A	A	Stable	N/A
[illegible]	P	P	P	Increasing	Extensive
[illegible]	A	P	P	Increasing	Moderate
[illegible]	P	P	P	Increasing	Slight
[illegible]					
[illegible]	P	P	P	Stable	N/A
[illegible]	P	P	P	Stable	N/A
[illegible]	A	A	A	Stable	N/A
[illegible]	P	P	P	Increasing	Slight
[illegible]	P	P	P	Increasing	Slight
[illegible]	A	A	A	Stable	N/A
[illegible]					
[illegible]	P	A	A	Decreasing	Slight
[illegible]	P	P	P	Stable	N/A
[illegible]	P	P	A	Decreasing	Extensive
[illegible]	P	P	P	Decreasing	Slight
[illegible]	P	P	P	Increasing	Moderate
[illegible]	A	A	A	Stable	N/A
[illegible]	A	A	A	Stable	N/A
[illegible]	A	A	A	Stable	N/A
Subalpine Meadow	A	A	A	Stable	N/A
Alpine Heath	A	A	A	Stable	N/A
Alpine Meadow	A	A	A	Stable	N/A

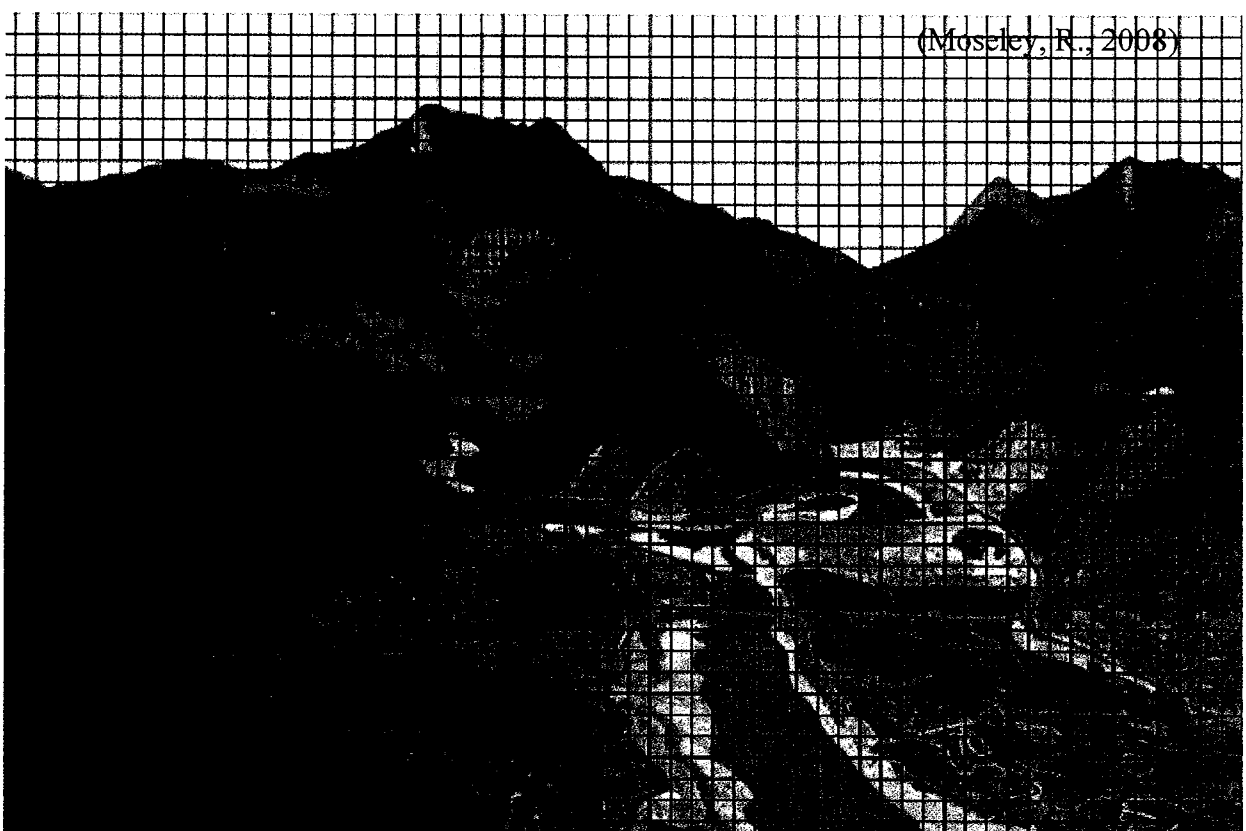
4.4.3.2 Simple Grid Analysis of Photo Set #3

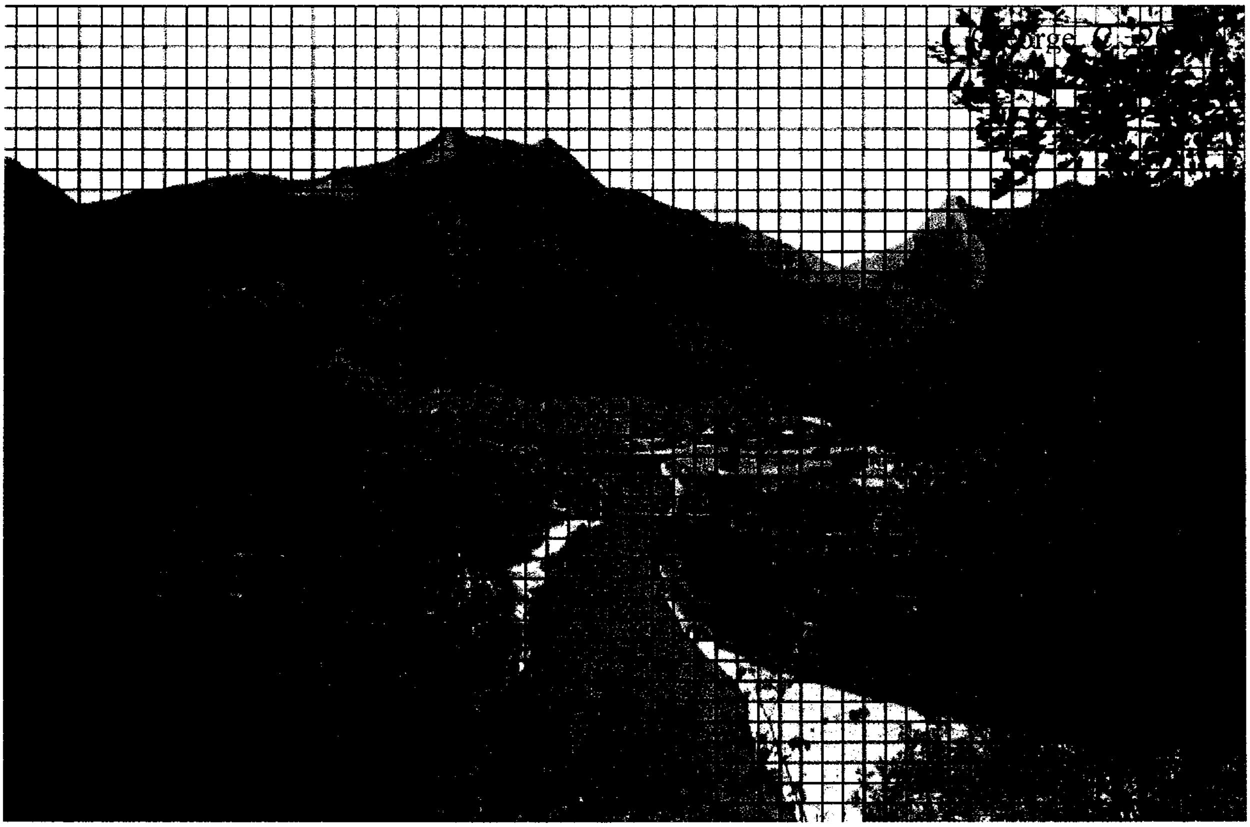
The photo area occupied by settlement increased (shown in magenta in **Figure 4.15**). Where the percentage photo area occupied by settlement was 0.43% in Rock`s photograph, it has since increased to 1.59% in the photograph taken in 2008. The increase in population is concentrated in the valley in the center of the photograph. In contrast to the area occupied by settlement, the area occupied by agricultural and pasture land has decreased. Agricultural and pasture lands occupied 17.18% and 1.09% of the photo are in 1923, respectively. In the 2008 photograph, the percentage photo area had decreased to 9.53% for agricultural lands and 0.66%, for pasture lands (shown in dark peach and medium peach, respectively).

The arid grassland (shown by very light green in Figure 4.15) that was present in 1923, occupying 1.03% of the photo area has since been replaced by other forms of land use. Much of the arid grassland that was present in the historic photograph has been degraded to human-impacted wasteland (shown as stripes of light pink and very light green); the area occupied by this landscape classification went from occupying 0.97% of the photograph in the historic photograph to occupying 1.42% of the photo area in 2003, and then 2.03% in 2008. Also, much of the area occupied by arid grassland in the historical photograph is now occupied by a power generation station, marked as industrial infrastructure (shown in red on the middle-right of the photograph). While no area was occupied by industrial infrastructure in the historical photograph, industrial infrastructure occupied 0.03% of the 2003 photograph and 0.16% of the photo area of the 2008 photograph. There was a notable increase in the power infrastructure present between the 2003 photograph and the 2008 photograph.

Figure 4.15 Photo Set #3 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend.







The photo area occupied by arid shrubland has decreased slightly between the historic photograph and those more recent photographs. Arid shrubland occupied 3.22% of the photo area in Rock`s photograph, 2.61% of the photo area in Moseley`s photograph, and 2.46% in my photograph (shown in light green). Much of the area occupied by arid shrubland in the historical photograph is now occupied by the power station, with the surrounding landscape deemed human-impacted wasteland. In the recent photographs, the shrubland is concentrated in the center of the photograph, where the implementation of the hydro lines has prompted the deforestation of the surrounding landscape.

According to the Simple Grid Analysis, woodlands have decreased notably (shown in a light olive green). Where woodlands occupied 6.19% of the photo are in 1923, there are no woodlands present in the 2008 photograph. Similarly, warm *Pinus* forest has

Table 4.9 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #3 using Simple Grid Analysis.

Photo Set #3 – Simple	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
[illegible]						
[illegible]	7	0.43	38	2.15	29	1.59
[illegible]	1	0.06	41	2.32	20	1.10
[illegible]	0	0.00	0.5	0.03	3	0.16
[illegible]	283	17.18	222	12.57	174	9.53
[illegible]	18	1.09	14	0.79	12	0.66
[illegible]	38	2.31	138	7.82	201	11.01
[illegible]	0	0.00	21	1.19	59	3.23
[illegible]	16	0.97	25	1.42	37	2.03
[illegible]						
[illegible]	69	4.19	53	3.00	54	2.96
[illegible]	14	0.85	62	3.51	65	3.56
[illegible]	77	4.68	53	3.00	132	7.23
[illegible]	93	5.65	81	4.59	155	8.49
[illegible]						
[illegible]	17	1.03	0	0.00	0	0.00
[illegible]	53	3.22	46	2.61	45	2.46
[illegible]	102	6.19	24	1.36	0	0.00
[illegible]	849	51.55	909	51.49	754	41.29
[illegible]	11	0.67	38	2.15	86	4.71

decreased according to the values generated through Simple Grid Analysis. Where warm *Pinus* forest occupied 51.55% of the landscape in the historic photograph and 51.49% in the 2003 photograph, warm *Pinus* forest only occupies 41.29% (shown in dark forest green). This decrease is primarily caused by the differences in the photo point. Because I could not retake the photograph from the exact photo point, the hill present in the left foreground of the landscape photo is not as large. Using Simple Grid Analysis, this greatly decreases the percentage photo area occupied by warm *Pinus* forest in the 2008 photograph. In contrast, there has been a noted increase in the area occupied by mixed forest (shown in emerald green). Where mixed forest occupied only 0.67% of the photo area in 1923, it occupied 4.71% of the photo area in 2008.

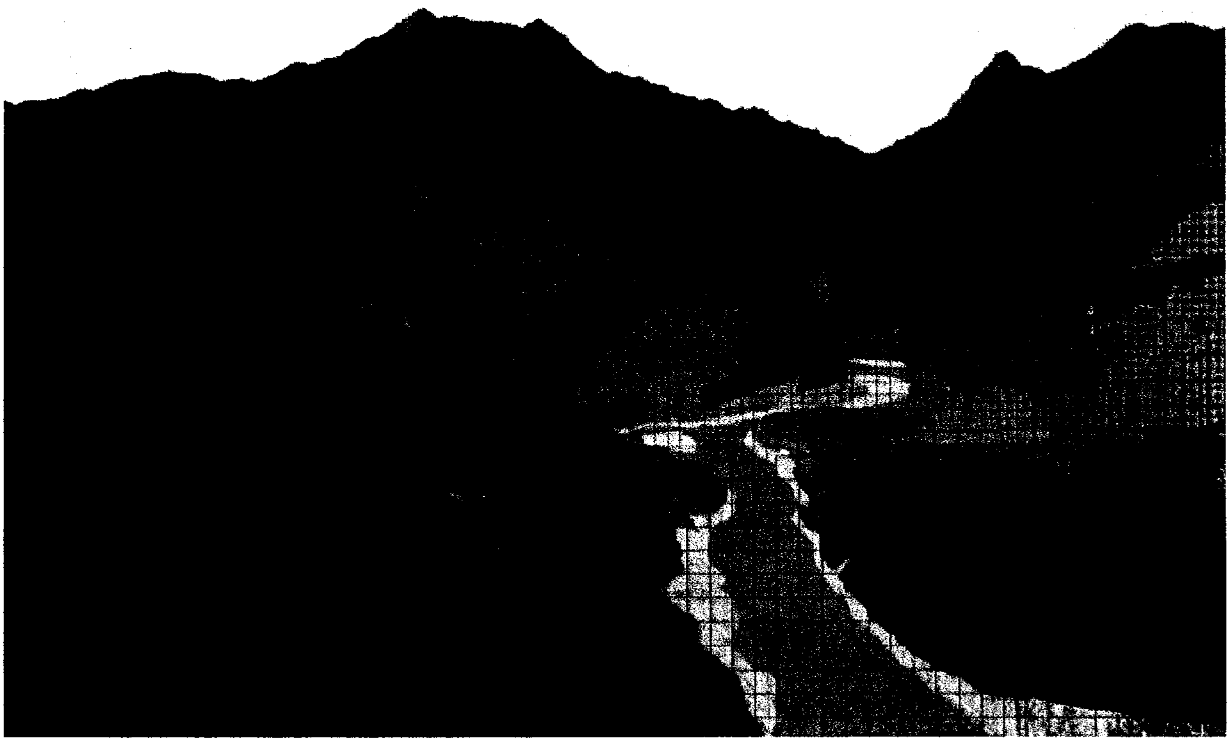
The photo area occupied by exposed stable geomorphology has decreased over the past century. In 1923, 4.19% of the photo area was occupied by stable geomorphology; it then decreased to 3.00% in 2003, and then to 2.96% in 2008 (shown in light brown). This decrease has been partially caused by an increase in the density of vegetation. Mass wasting has increased from occupying 0.85% of the photograph in 1923 to occupying 3.56% of the photo area in 2008 (shown in dark brown). Fluvial hydrology and fluvial geomorphology have both increased according to Simple Grid Analysis, increasing from 5.65% and 4.68% to 8.49% and 7.23% of the photo area respectively (shown in the lower middle of the photograph in blue and gold). These values have not changed greatly, reflecting very little change to the fluvial hydrology in this area. I have taken the values generated using Mosley's photograph out of this conversion because the foreground present in both the historic photograph and the photograph taken for this study is cut off in Moseley's photograph, greatly screwing the percentage of the photo area occupied by these landscape features. For a summary of the information gained through Simple Grid Analysis, please consult **Table 4.9** (p.114).

4.4.3.3 Scaled Grid Analysis of Photo Set #3

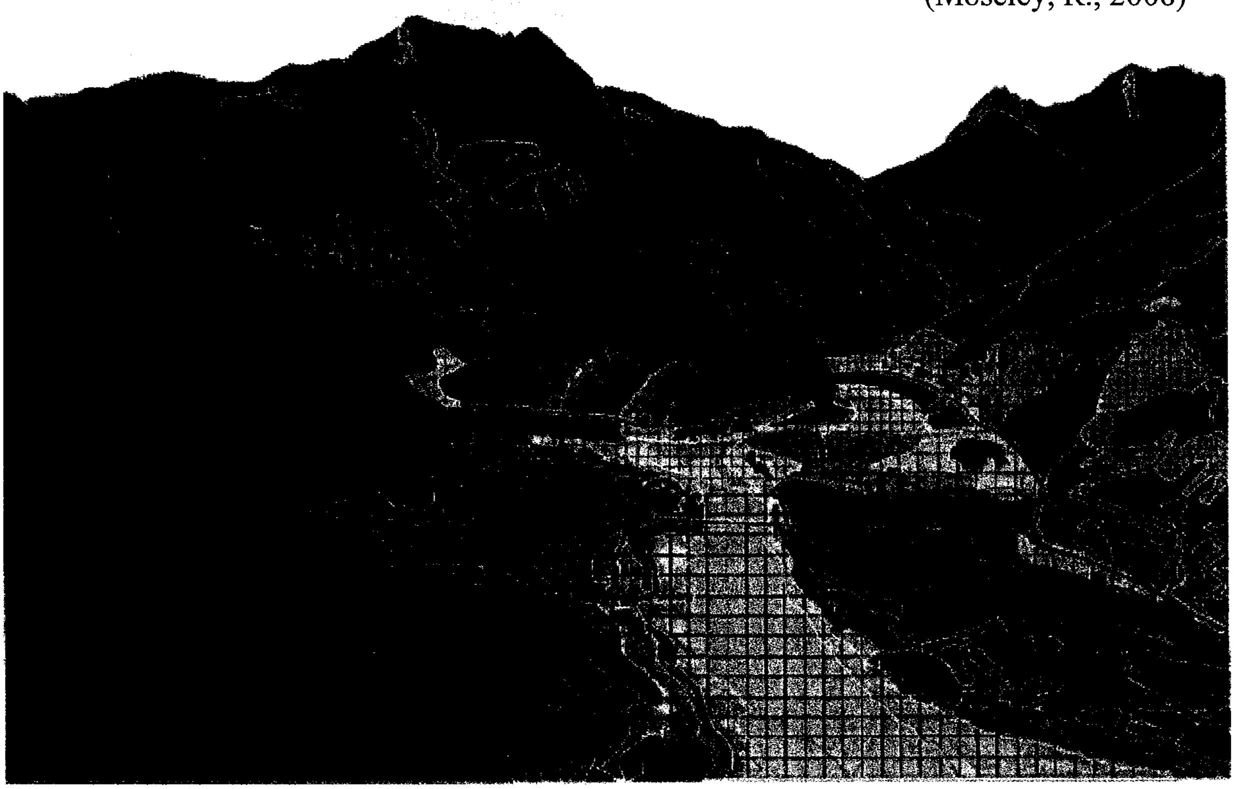
In general, all of the landscape classifications that are classified under `land use` and `landscape features` (see **Table 4.10**, p. 118) show the same trends indicated through using Simple Grid Analysis. There is, however, a notable difference between the percentage of the photo area occupied by each land use and the percentage of the landscape occupied by each land use. According to Scaled Grid Analysis, the landscape area occupied by settlement did increase, however, the landscape area occupied were 0.26% of the landscape shown within the photograph in 1923, 0.78% in 2003, and 1.05% in 2008.

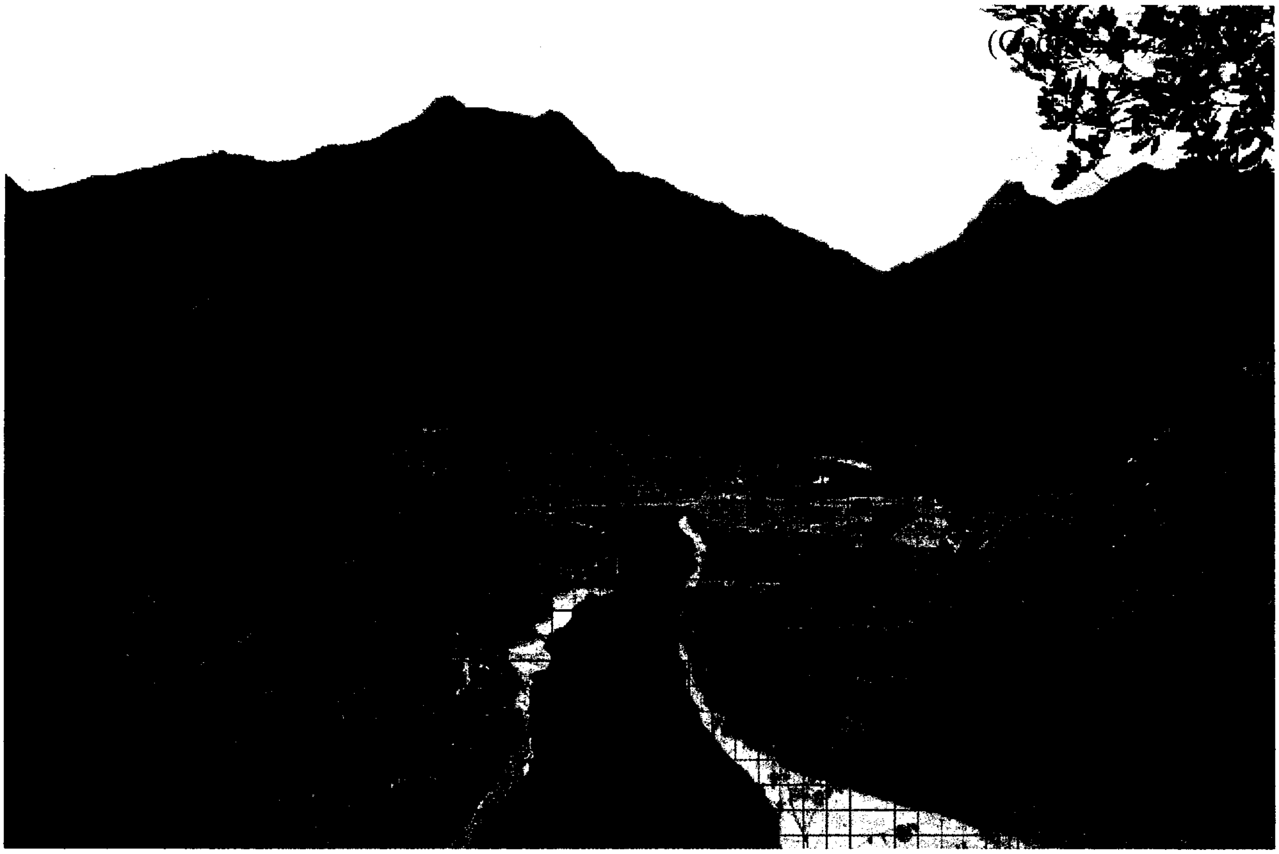
Figure 4.16 Photo Set #3 with scaled grids that have been calibrated to fit the landscape overlaid. Also, the colour-coded distributions of vegetation communities have been added.

(Rock, J., 1923)



(Moseley, R., 2008)





Similarly, Scaled Grid Analysis revealed that the landscape area occupied by agricultural lands was decreasing from occupying 4.31% of the photographed landscape in the historical photograph to 2.62% in 2003 to 3.02% in 2008. The area occupied by grazing lands using Scaled grid Analysis contrasted Simple Grid Analysis in that Scaled Grid Analysis showed that the area occupied by grazing pastures was relatively stable, occupying 1.27% of the photographed landscape in 1923, 1.04% in 2003, and 1.19% in 2008.

Whereas Simple Grid Analysis revealed that the photo area occupied by warm *Pinus* forest was decreasing, occupying 51.55% of the photo area in 1923, 51.49% in 2003, and then dropping to 41.29% in 2008, Scaled Grid Analysis shows that the landscape area occupied by warm *Pinus* forest has actually shown an increase over the past century,

Table 4.10 This table shows the results of the Scaled Grid Analysis for Photo Set #3. The first column shows the number of squares occupied by each landscape classification in each photograph (Rock, Moseley, George). In the second column, the number values are calculated into percentages of the total number of squares in each photograph.

Photo Set #3 - Scaled	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
[illegible]	18	0.26	73	0.78	68	1.05
[illegible]	0	0.00	50	0.54	41	0.64
[illegible]	0	0.00	5	0.05	12	0.19
[illegible]	295	4.31	244	2.62	195	3.02
[illegible]	87	1.27	97	1.04	77	1.19
[illegible]	60	0.88	127	1.36	164	2.54
[illegible]	0	0.00	95	1.02	194	3.01
[illegible]	33	0.48	155	1.66	185	2.87
[illegible]	577	8.43	475	5.09	492	7.62
[illegible]	59	0.86	267	2.86	234	3.63
[illegible]	147	2.15	126	1.35	184	2.85
[illegible]	95	1.39	96	1.03	134	2.08
[illegible]	63	0.92	0	0.00	0	0.00
[illegible]	202	2.95	30	0.32	131	2.03
[illegible]	385.5	5.63	161	1.73	0	0.00
[illegible]	4810.5	70.29	7188	77.05	4890	75.74
[illegible]	12	0.18	29	0.31	108	1.67

occupying 70.29% of the landscape photographed in 1923, 77.05% in 2003, and 75.74% in 2008. The reasons for these differences will be discussed in Chapter 5.

As well as the landscape photographs taken by Joseph Rock in the early part of the twentieth century, historical writings offered by other botanical explorers help to reconstruct the historical landscape of the First Bend of the Yangtze in the early 1900s.

4.5 Literary Results

As previously mentioned in Chapter 2, northwestern Yunnan attracted botanical enthusiasts, geographical explorers, and seed collectors during the early part of the 20th century. At the forefront of the geographical and botanical explorers were both Francis Kingdon-Ward and Heinrich Handel-Mazzetti. I used their detailed records of the biogeography that they encountered on their expeditions through northwestern Yunnan to reconstruct the botanical landscape of the area around the First Bend of the Yangtze during the early 20th century. Further, this section offers the reader the results of my vegetation analysis. I use this information, along with the results of my rephotography study, to compare the landscape that existed 100 years ago to the landscape that exists there at present.

4.5.1 Heinrich Handel-Mazzetti

Handel Mazzetti describes the vegetation communities that he encountered in China with great detail (Winstanley, 1996). He spends a significant amount of time exploring the biogeography of Yulong Shan, specifically within Tiger Leaping Gorge. He provides detailed recordings of the distributions of vegetation communities, as well as the unique floral species that he encountered on his journeys.

Handel-Mazzetti discusses the vegetation of the upstream parts of the First Bend of the Yangtze as being "somewhat dreary" and most of the interesting and notable flora he describes as "drought-loving". He does highlight the presence of subtropical orchids, *Dendrobium clavatum* and *Vanda rupestris*, (Handel-Mazzetti, 1927, Ch. 23). Within Tiger Leaping Gorge, Handel-Mazzetti records the xerophytic plants that reside within the subtropical zone (Handel-Mazzetti, 1927). Along the riverbanks of the Yangtze, Handel-Mazzetti comments on the diversity of xerophytes that run the river's edge (Handel-Mazzetti, 1927). Downriver from the First Bend of the Yangtze, Handel-Mazzetti describes the landscape:

> Steep ravines led down to the river valley, the bottom of which as out of sight. Narrow ridges and rugged summits jutted out between them and plunged down in vertical rock precipices or steep, barren. Constantly shifting

> screes. There was still some woodland, but only near the top; lower down everything was dried up and, at first, sight devoid of plant life. (Handel Mazzetti, 1927, Ch. 2).

Handel-Mazzetti describes the First Bend of the Yangtze as being extremely arid, with the dominant vegetation communities including arid grasslands, arid shrublands, and woodlands.

Handel-Mazzetti introduces savannah woodland as a vegetation community where herbaceous floras including *Rumex hastatus*, *Cystacanthus yunnanensis,* as well as many other species of the family Acanthaceae, are concealed by the tall grasses. The taller shrubs and trees in this landscape include *Nouelia insignis* and *Quercus dilatata. Bombax malabarica* and *Erythrina stricta*, as well as *Opuntia monacantha*, an introduced species from America, were also present. This vegetation community is able to withstand the arid environment of the Yangtze River Basin.

Not all of the vegetation communities that Handel-Mazzetti found within the First Bend of the Yangtze were adapted to suite an arid environment. Here, Handel-Mazzetti notes the other types of vegetation communities that he encounters while ascending the limestone cliffs bordering the Yangtze River at Zhazi:

> Having climbed out of the arid depths of the river gorge we were once more in subtropical maquis consisting of *Pistacia weinmannifolia* with *Vitex* and *Ziziphus* bushes, succeeded at 2400m by bright green *Pinus yunnanensis* woodland. We climbed up through the next vegetation zones in rapid succession – a forest of the darker, short-needles *Pinus tabuliformis* interspersed with oaks, and temperate zone of mixed woodland, with much bamboo, running down into a little ravine…The pass was at 3700m; standing on a lush meadow we gazed over the Yongning Basin, but low clouds hid the mountain tops and cast gloom over the green landscape. (Handel-Mazzetti, 1927, Ch.17)

Handel-Mazzetti notes the plant cover of *Pinus* and *Quercus* forest, similar to that found on the Yunnan plateau. He explains that the oaks, *Lithocarpus spicata* var. *colletti* and

Figure 4.17 A vegetation community dominated by *Quercus* and bamboo within the temperate zone of Tiger Leaping Gorge on the slopes of the Yangtze River.

Quercus aliena, live under the pines. As well, he mentions gorges filled with *Lithocarpus* forest containing *Edgeworthia gardneri* (Handel-Mazzetti, 1927). While climbing Longzhu Shan, he notes seeing evergreen oak forest, comprised of *Lithocarpus variolosa*, *Quercus schottkyana* and *Thea speciosa*, at around 2650m and a *Quercus semecarpifolia*/Bamboo vegetation community at higher elevations (Handel-Mazzetti, 1927).

Within Tiger Leaping Gorge, Handel-Mazzetti notes the vegetation belts on the mountainsides banking the Yangtze River:

> Just above the river was the subtropical zone – steep slopes, grey or yellow in couus, with scattered scrub; next came the warm temperate zone – red steppe dotted with pale green pines; above this were the temperate zone mixed forests in their multicoloured autumnal garb, then the dark green subalpine fir forests, above them the high alpine zone, here certainly barren, grey and windswept and finally the snow-capped spires. (Handel-Mazzetti, 1927, Ch.29)

Handel-Mazzetti also describes the high-altitude environment well. At just below 4000m, Handel-Mazzetti notes fir woods and discusses looking down in to abundantly wooded river valleys. He observes several species of *Rhododendron*, *Primula,* and the creeping moss *Hemiphragma heterophyllum.* At 4750m, the mountains of Yulong Shan were alpine meadows, covered with *Delphinium forrestii* and blue gentians. I noted this passage specifically because, for the most part, both Handel-Mazzetti and Kingdon Ward describe the landscape of the First Bend of the Yangtze as being extremely arid.

As well as discussing the vegetation change in relation to altitude, Handel-Mazzetti also describes the spatial variation of vegetation communities based on aspect. He notes that the eastward facing side of Yulong Shan has remarkably different vegetation than the slopes bordering the Yangtze River. Whereas the slopes bordering the Yangtze River are dominated by dry forests of *Pinus tabulaeformis* ascending to "uncommon" altitudes, Handel-Mazzetti discusses 'luxuriant meadows' that occupy altitudes of around 3300-3500m that fragment dark stands of fir on the eastern side of Yulong Shan. He comments on the dense grey mosses, notably *Orthotrichum hookeri*, and lichens, such as *Oropogon loxensis*, that cover the shrubs at these altitudes. During his treks up the eastern slopes of Yulong Shan, Handel-Mazzetti describes traveling through 'splendid forest and bamboo, dripping with moisture' and notes the presence of flowering *Azaleas*. He remarks on the presence again of the parasitic species *Loranthus calorias* and the presence of the beardmoss species, *Usnea longissima*, hanging from the trees (Handel-Mazzetti, 1927, Ch.8).

As well as aspect, altitude and slope governing the special distribution of vegetation communities, the natural barriers created by the mountain ranges being cut by parallel river systems prevents the east-west dispersal of species and promotes allopatric speciation.

Handel-Mazzetti discusses the example of the presence of *Diapensia purpurea* on Haba Shan and notes that this species, as well as many species of moss are characteristic of the high mountain ranges that are further to the west and do not appear east, across the Yangtze River, on Yulong Shan (Handel-Mazzetti, 1927).

Within their written records of the ecological landscape of northwestern Yunnan in the early 20th century, Handel-Mazzetti and Kingdon-Ward also record significant human interactions with the natural landscape. Both explorers are able to frequently seek refuge within villages, suggesting that the population of northwestern Yunnan was significant during the early part of the twentieth century. They also describe the paths that they use to navigate the region. Both explorers record significant agriculture. Within the First Bend of the Yangtze, Handel-Mazzetti notes the growth of opium poppy plants being cultivated near the roadsides (Handel-Mazzetti, 1927). He also records terraced rice fields in Washua at about 2500m (Handel-Mazzetti, 1927). Handel-Mazzetti discusses deforestation for timber use and agricultural expansion near Bede. The agricultural crops that he notes include oats, barley, buckwheat, and potatoes and, at the village of Huili, he notes rice and bean fields (Handel-Mazzetti, Ch.3). Handel-Mazzetti also discusses the presence of yak pasture on Haba Shan at approximately 4030m. He describes the vegetation as being "short as if it had been mown" (Handel-Mazzetti, Chapter 14). He describes the landscape as only being comprised of low-growing grasses and herbs that are able to survive despite intense grazing. These would include species such as *Aster likiangensis*.

Reconstructing the historical distribution of vegetation communities based on the historical writings of Handel-Mazzetti was not without challenges. A significant number of the Latin binomials that Handel-Mazzetti used as species names have been renamed since the early 1900s. Therefore, it was extremely difficult to make an accurate comparison.

Table 4.11 (p.125-127) offers a list of the botanical species that Handel-Mazzetti discussed, including the current family, genus and species name for each specimen, the name that he used to refer to each species, as well as the name of the author for each species. Handel-Mazzetti would frequently use only the genus name to discuss the botanical landscape in his writing. So, in this table, I have added the species that I hypothesize were present during his travels. Finally, those species that I could not find an author for are labeled as 'unknown', and those species that I could not identify an author for to the species level, but could find the author of the Genus, are marked with '- *Genus*'.

4.5.2 Frank Kingdon-Ward

Although Kingdon-Ward does mention vegetation in his writings, he primarily focuses on the indicator species within vegetation communities, rather than detailing the floristic environment of each area explored. Commonly, Kingdon-Ward uses only the genus name to describe the vegetation present. He focuses on the abiotic precursors to vegetation distribution, such as slope, aspect, temperature, and availability of water. In many of his papers, Kingdon-Ward focuses on the abiotic environment of northwestern Yunnan, specifically on the glaciers.

The spatial distribution of vegetation communities varies significantly according to slope aspect within the First Bend of the Yangtze. On the north-facing slopes, Kingdon-Ward describes a vegetation community of *Larix* and *Picea* that gives way to a thick scrubland of *Rhododendron*, *Berberis*, and *Juniperis* at altitudes above 16, 000 feet (4877m). The south-facing slopes reveal a much different ecosystem composition. The treeline on the south-facing slopes occurs at a much lower altitude, and scrub growth occurs much lower. This contrast can be attributed to the difference in hydrology caused by the

Table 4.11 Cataloguing Plant Names. This table lists the botanical species discussed by Handel-Mazzetti. The table includes the Latin name, the name used for each spp. In Handel-Mazzetti's writings and the author of each *spp*. name.

Family	*Genus species*	Handel-Mazzetti`s name	Author
Acanthaceae (isotype)	= Phlogacanthus	*Cystacanthus yunnanensis*	Nees (1832) - *Genus*
Alectoriaceae or Parmeliaceae depending on literature	*Oropogon loxensis*	*Oropogon loxensis*	Neck. (1790) - *Genus*
Anacardiaceae	*Pistacia weinmanniifolia* Also called: *Pistacia coccinea*	*Pistacia weinmanniifolia*	Poisson ex. Franchet, Bull. (1886)
Asteraceae	*Nouelia insignis*	*Nouelia insignis*	Franch. (1889)
	Aster likiangensis	*Aster likiangensis*	Franch. (1896)
Bombacaceae	*Bombax ceiba*	*Bombax malabarica*	L. (1753)
Cactaceae	*Opuntia monacantha*	*Opuntia monacantha*	Haworth. (1819)
Cupressaceae	*Cupressus duclouxiana*	*Cupressus spp.*	Hickel (1914)
Diapensiaceae	*Diapensia purpurea* Has been called: *Diapensia bulleyana*	*Diapensia purpurea*	Diels (1912)
Ericaceae	*May be a subspecies of Rhododendron arboreum*	*Rhododendron delavayi*	Sm.(n.d.)
	Rhododendron edgeworthii	*Rhododendron spp.*	Hook.f. (n.d.)
	Rhododendron irroratum	*Rhododendron irroratum*	Franch. (1887)
	Rhododendron lepidotum	*Rhododendron sinolepidotum*	Wall. Ex G.Don (1934)
	Rhododendron siderophyllum	*Rhododendron obscurum*	Franch. (1898)
Fabaceae	*Erythrina stricta*	*Erythrina stricta*	Roxb. (n.d.)
Fagaceae	*Castanopsis delavayi*	*Castanopsis spp.*	Franch. (1899)
	Castobalanopsis delavayi	*Cyclobalanopsis spp.*	unknown
	Cyclobalanopsis glaucoides	*Cyclobalanopsis spp.*	Schottky (1912)
	Lithocarpus dealbatus	*Lithocarpus dealbata*	Rehder (1919)
	Lithocarpus elegans	*Lithocarpus spicata var. collettii*	Blume (1970)
	Lithocarpus variolosus Has been called: *Lithocarpus chienchuanensis, L. hui, L. leucostachyus, Pasania hui, P. variolosa, Synaedrys variolosa*	*Lithocarpus variolosa*	Chun (1928)
	Quercus aliena	*Quercus aliena*	J.G. Jack (1909)
	Quercus aquifolioides	*Quercus spp.*	Rehder & E.H. Wilson (1916)
	Quercus cocciferoides Has been called:	*Quercus cocciferoides*	Hand.-Mazz. (1925)

	Quercus cocciferoides var. taliensis, Q. taliensis		
	Quercus dentate	*Quercus spp.*	Thunb. (1784)
	Quercus dilatata var.	*Quercus dilatata*	Royle (1836)
	Quercus franchetii	*Quercus franchetii*	Skan (n.d.)
	Quercus guyavifolia Has been called: *Quercus aquifolioides var. rufescens, Q. ilex, Q. pileata, Q. semecarpifolia var. Rufescens*	*Quercus pannosa*	H.Lév. (1913)
	Quercus monimotricha	*Quercus spinosa var. monimotricha*	Hand.-Mazz. (1929)
	Quercus schottkyana	*Quercus schottkyana*	
	Quercus semecarpifolia also called *Quercus obtusifolia*	*Quercus semecarpifolia*	Sm. (n.d.)
	Quercus senescens	*Quercus senescens*	Hand.-Mazz. (1929)
	Quercus yunnanensis	*Quercus spp.*	Franch.(1899)
Hydrangeaceae	*Hydrangea xanthoneura*	*Hydrangea xanthoneura*	Diels (n.d.)
Juglandaceae	*Juglans regia*	*Juglans spp.*	L. (1753)
	Juglans sigillata	*Juglans spp.*	Dode (1906)
Loranthaceae	*Taxillus caloreas* Variants: *var. caloreas and var. fargesii*	*Loranthus caloreas*	(Diels) Danser (1933)
Orchidaceae	*Dendrobium clavatum*	*Dendrobium clavatum*	Roxb. (n.d.)
	Vanda rupestris	*Vanda rupestris*	Hand.- Mazz. (1925)
Orthotrichaceae	*Orthotrichum hookeri*	*Orthotrichum hookeri*	Wils. Ex Mitt. (n.d.)
Parmeliaceae	*Dolichousnea longissima*	*Usnea longissima*	unknown
Pinaceae	*Abies georgei*	*Abies spp.*	Hand.-Mazz. (1929)
	Larix potaninii	*Larix pataninii var. australis*	Batalin (1894)
	Larix speciosa	*Larix spp.*	W.C. Cheng & Y.W. Law
	Picea likiangensis	*Picea spp.*	E. Pritz. (1900)
	Pinus armandii	*Pinus spp.*	Franch. (1884)
	Pinus tabuliformis	*Pinus tabulaeformis*	Hort. Ex Carrière (1867)
	Pinus yunnanensis	*Pinus yunnanensis*	Franch. (1899)
Polygonaceae	*Rumex hastatus*	*Rumex hastatus*	D.Don (1825)
Primulaceae	*Primula littoniana* Also known as: *P. vialii*	*Primula littoniana*	Forrest (1908)
	Lysimachia deltoidea var. Cinerascens	*Demodian cinerascens*	Wight (n.d.)
	Primula yunnanensis	*Primula yunnanensis*	Franch. (1885)
Ranunculaceae	*Aconitum coriophyllum*	*Aconitum coriophyllum*	Hand.-Mazz. (1925)
	Clematis delavayi	*Clematis delavayi*	Franch. (1886)
	Delphinium forrestii	*Delphinium forrestii*	Diels. (1912)
Rosaceae	*Pentaphylloides fruticosa* *Dasiphora fruticosa*	*Potentilla fruticosa*	O.Schwarz (1949)

	Potentilla fruticosa		
	Rosa lichiangensis	*Randia lichiangensis*	T.T. Yu & T.C. Ku (1981)
	Sorbus koehneana	*Sorbus spp.*	C.K. Schneid. (1906)
	Sorbus rehderiana	*Sorbus spp.*	Koehne (1913)
Scrophulariaceae	*Hemiphragma heterophyllum*	*Hemiphragma heterophyllum*	Wall. (1822)
Thymelaeaceae	*Edgeworthia gardneri* Has been called: *Daphne gardneri*	*Edgeworthia gardneri*	Meisn. (1841)

slope aspect. The mountains sides facing the north are not exposed to the warm spring sunlight; therefore, the spring melt has a longer duration, allowing a constant water supply for germinating plants, as well as a form of insulation from drastic changes in temperature. In contrast, any snow present on the south-facing slopes during the winter months disappears rapidly in the spring sunshine, exposing vegetation a harsh environment of rapidly changing temperature and little water (Kingdon-Ward, 1920).

Kingdon-Ward notes the advanced deglaciation on the eastern mountain ranges in northwestern Yunnan, specifically within the Mekong-Yangtze divide, in comparison to the more western ranges. He describes the glaciers on the eastern ranges as being 'generally extinct' (Kingdon-Ward, 1922, p. 363). The trend of deglaciation increases from west to east, as the climate grows drier. He suggests that this is because of the progressive elevation of the river divides: those further west having been elevated first, and are higher, thus gradually cutting off the rain-bearing winds from the southwest because of the multiple rain shadows. As a result of these rain shadows, the Yangtze River Valley as an extremely arid landscape in comparison to the basins found further to the west. He notes no tree growth and describes the valley as having "only a scanty covering of highly specialized vegetation on the slopes", noting that the valley appears to be a "long grey or khaki-coloured corridor" (Kingdon-Ward, 1920, p. 184).

Kingdon-Ward also explains the state of the glaciers in the early 20th century within the First Bend of the Yangtze and along the Mekong-Yangtze divide. He describes the Mekong-Yangtze divide as the mountain range that boasts the highest peaks in the area (6100-6400m), but notes that there are relatively few glaciers in comparison to the other ranges, and the glaciers that do exist are in "an advanced state of dissolution" (Kingdon-Ward, 1920, p. 186). He mentions records of extensive glaciation in the past and physical evidence of glacial valleys. He makes particular reference to the Pai-ma Shan peak (Baima Shan), saying that, "its shrunken glaciers cling fungus-like to the rock slopes, and with the blunt arms outthrust crawl solemnly forward" (Kingdon-Ward, 1920). He also noted a rapid retreat in 1911 and 1912. Kingdon-Ward describes the crest of the range as being 'sierra-like', with coniferous forests and evergreen oak at lower altitudes. As well, he notes very little deciduous forest, bamboo or meadow. Kingdon-Ward warns about the possible desiccation of the high-altitude environment through the diminution of the glaciers. He identifies species of *Primula, Rhododendron, Gentiana*, *Delphinium* and *Campanula* as being threatened if the environmental trend that he notes occurring continues.

4.5.3 Fieldwork – This Study

Within northwestern Yunnan, the population density is low, especially in comparison to the rest of China. The local people who live in the rural areas of the First Bend of the Yangtze River practice traditional subsistence farming and agriculture. Common crops that were being grown in 2008 included rice, corn, cabbage, onions, and barley, Herds of sheep, goats, and cows were commonly seen grazing in the pasture lands. Very little machinery is used by the local population for agricultural production. The agricultural lands have not expanded over the past century despite the noted increase in population. I noted several areas where agricultural lands had been left to regenerate. Settlements are constrained to the valleys within the Yangtze River basin, with few living high within the mountains. The low-lying areas that are not occupied by settlements have very little tree growth; however, the mountains are covered with various forest vegetation communities.

The recent implementation of road and hydro infrastructure has caused some noted changes to the natural environment. There is notable mass wasting around roadways that occur on steep slopes. As well, noted deforestation has occurred in order to build hydro towers. This infrastructural development is closely linked to the tourism development in northwestern Yunnan.

The vegetation communities described by Kingdon-Ward and Handel-Mazzetti in the early twentieth century match well with the vegetation communities that I found within the Upper Yangtze River Valley in 2008. For instance, the spatial distribution of vegetation communities described by Handel-Mazzetti was also supported through my own fieldwork. Typically, the lower banks of the Yangtze River Basin were dominated by a mixture of arid grasslands and shrublands, including species of *Vitex* and *Bombax*. Ascending the slopes of the Yangtze Basin, the vegetation communities transformed into woodlands dominated by *Pinus* (*Pinus* savannahs) and then gradually into *Pinus* forest. Only within the steep slopes of Tiger Leaping Gorge was this transition interrupted by a sclerophyllous *Quercus* forest. This vegetation community was located below the *Pinus* forest, from 2200 to 2500 meters above sea level. This vegetation community was dominated by *Quercus aquifoliodes* and bamboo with *Sorbus spp.* and species of *Rhododendron*. Within the Yangtze River Basin, *Pinus* forests showed some variance, where *Pinus armandii*, *Pinus yunnanensis,* and *Pinus densata* were identified within variants of the *Pinus* forest. Commonly, *Pinus yunnanensis* forest was found at lower altitudes. Species of *Quercus* and *Rhododendron* served as the understory of *Pinus* forests. Commonly occurring species were *Quercus longispica*, *Q. franchetii*, *Rhododendron delavayi*, and *Lithocarpus dealbatus*. I did notice that the distribution of *Pinus* forests extended to higher altitudes than seen outside of the First Bend of the Yangtze, specifically on the eastern side of Yulong Shan. Above the *Pinu*s forests were alpine forests, dominated *by Larix, Picea,* and *Abies spp.* These forests gave way to subalpine shrubalnds and meadows, and then the snow-covered peaks. The indicator species, as well as the charismatic floral species that I encountered during my fieldwork are found in **Table 4.12** (p.133).

There were also some noted differences between the historical landscape described by Kingdon-Ward and Handel-Mazzetti and the landscape that I saw in northwestern Yunnan in 2008. When I traveled through the First Bend of the Yangtze, I would not have described it a 'devoid of plant life' as did Kingdon Ward (1920); rather, I would describe the Yangtze Basin in this area as being intensely populated with species of *Pinus*, specifically *Pinus densata* and *Pinus yunnanensis*. His description of the arid environment that existed within the Yangtze River Basin 100 years ago leads me to investigate the possibility of increasing temperatures and precipitation levels since his explorations. These climatic changes would promote a less arid environment on the lower slopes of the Yangtze River Basin. I hypothesize that the slopes of the First Bend of the Yangtze have been increasingly populated by taller plants, specifically tree species. Also, through the comparison of the photo pairs, I was able to note a significant increase in the tree density within forest vegetation communities. This also indicates to an increase in available water on the slopes of the First Bend of the Yangtze.

I also noted that the vegetation communities did vary greatly according to aspect. The south-facing slopes presented a more arid environment of sclerophyllous species. As well, the western side of Yulong Shan was notably more arid than the eastern side. On the western facing side of Yulong Shan, within the Yangtze River Basin, Handel-Mazzetti records moist areas within the woods as having an understory of bamboo. Handel Mazzetti comments that the drier forests of the western facing side of Yulong Shan are dominated by *Pinus tabulaeformis,* which I think may be *Pinus armandii,* and that it ascends to uncommon altitudes (Handel-Mazzetti, 1927). While conducting vegetation sampling on the eastern side of Yulong Shan, I also noted the moister conditions, allowing for a denser and more species-rich vegetation pattern. I agree that the distribution of *Pinus* within the First Bend of the Yangtze extended to higher altitudes than seen in less arid environments.

4.6 Summary and Conclusions

Based on my rephotography study, my review of the historical literature, as well as my own fieldwork, I have found that, although there have been some notable changes, the overall ecological landscape and the land use patterns within the First Bend of the Yangtze have remained relatively stable over the past 100 years, with the exception of the development of transportation and industrial infrastructure. I will begin by providing a summary of my findings and provide some concluding thoughts.

First, the area occupied by housing and other buildings within the area of the First Bend of the Yangtze has increased over the past century. Also, the settlement pattern has changed and buildings are more densely packed within populated areas. For example, in Photo Set #16, the number of houses evident in the photographed landscape increased from eight houses in the historic photograph to over thirty houses by 2008. Using Scaled Grid

Analysis, the landscape area occupied by settlements has increased from 0.06% in the historic photograph to 0.23% in the photograph taken in 2008. As shown in Photo Set #3, the development of sophisticated transportation infrastructure, including two-lane bridges and highways along the steep slopes of the Yangtze River, are two engineering feats that have occurred over the past century. There has also been major development of power infrastructure within the First Bend of the Yangtze, as shown through the appearance of major power lines, towers, and generating stations in Photo Set #3. The development of new infrastructure has resulted in notable disturbance to the surrounding natural landscape. Forests have been cut to allow for clearance for hydro lines, erosion and mass wasting have occurred where roadways have been on steep slopes, and wastelands border the new infrastructural development.

Although the population of the First Bend of the Yangtze appears to have increased, the area occupied by traditional land use, such as agricultural land, has actually decreased. As evident in Photo Set #16 and Photo Set #3, the peripheral agricultural lands that were being used at the beginning of the 20th century have now been abandoned, or converted to forest plantations. In Photo Set #3, the landscape area occupied by agricultural lands has decreased from 4.31% of the landscape photographed to 3.02%. The areas occupied by arid grasslands and shrublands appear to have remained stable, or to have decreased. Photo Set #19 shows that the photo area occupied by arid vegetation types has decreased slightly, from 35.86% in 1923 to 34.27% in 2008. However, the area occupied by grassland has increased from 19.94% to 27.27%. The increasing arid grassland vegetation community within the arid environment may indicate an increase in grazing in this area, which is known to prevent the encroachment of woody species (Bailey *et al.,* 1990). Other forms of land use, including mining and forestry, have also increased in the area. Where Photo Set

Table 4.12 Cataloguing Plant Names. This table lists the botanical species recorded during my fieldwork in 2008. The table includes the Latin name, and the author of each species name.

Family	*Genus species*	Author
Araceae	*Arisaema erubescens*	Schott (n.d.)
	Arisaema costatum	Wall. (1832)
Berberidaceae	*Berberisspp. (may be Berberis pruinosa)*	
Betulaceae	*Alnus nepalensis*	D.Don (1825)
	Betula utilis	D.Don (1825)
Bignoniaceae	*Incarvillea mairei*	Griers. (1961)
Boranginaceae	*Eritrichium canum*	Kitam. (1963)
Cactaceae	*Opuntia monacantha*	Haworth. (1819)
Ericaceae	*Lyonia villosa*	Hand.-Mazz. (1936)
	Rhododendron decorum	Franch. (1887-88)
	Rhododendron edgeworthii	Hook.f. (n.d.)
	Rhododendron spinuliferum	Franch. (1895)
Fagaceae	*Castobalanopsis delavayi*	Unknown
	Cyclobalanopsis glaucoides	Schottky (1912)
	Lithocarpus dealbatus	Rehder (1919)
	Lithocarpus elegans	Blume (1970)
	Quercus aquifolioides	Rehder & E.H. Wilson (1916)
	Quercus dentata	Thunb. (1784)
	Quercus franchetii	Skan (n.d.)
Gentianaceae	*Gentiana veitchorium*	
Juglandaceae	*Juglans regia*	L. (1753)
	Juglans sigillata (cultivated)	Dode (1906)
	Juglans mandshurica	Maxim. (1856)
Pinaceae	*Abies ernestii*	Rehder (n.d.)
	Abies georgei	Hand.-Mazz. (1929)
	Picea branchytyla	Franch. (1900)
	Picea likiangensis	E. Pritz. (1900)
	Pinus armandii	Franch. (1884)
	Pinus densata	Masters (1906)
	Pinus yunnanensis	Franch. (1899)
	Tsuga dumosa	Eichl. (1887)
Primulaceae	*Primula blini*	
	Primula bathangensis	Petitm. (1908)
	Primula aromatica	W.W. Smith and Forrest (1923)
Rosaceae	*Fragaria spp.*	
	Rubus spp.	
	Sorbus spp.	
Salicaceae	*Populus yunnanensis*	Dode (1905)
	Salix heteromera	Hand.-Mazz. (1929)
	Salix sphaeronymphoides	Y.L. Chou (1979)

#16 showed no evidence of mining in the historical photograph, there was evidence of mining in the recent photographs within the confluence.

Photo Set #3 showed that the presence of mixed forest has increased over the past century, while the area occupied by woodlands and *Pinus* savannahs has decreased. Based on the photo sets, the overall area occupied by warm *Pinus* forests has stayed about the same; however, warm *Pinus* forests have replaced many woodland and *Pinus* savannah ecosystems, while mixed forests have replaced many areas previously occupied by warm *Pinus* forest. Based on my analysis, the area occupied by subalpine conifer forests has not changed; however, there has been a notable ascent in the treeline in some areas, such as Yulong Shan, shown in Photo Set #19.

Further, the water levels of the Yangtze River within the First Bend of the Yangtze appear to have dropped slightly based on the evidence in my photosets. Also, based on the presence of vegetation on islands within the Yangtze River, there appears to be a significant seasonal variation in water level, as well as fewer episodes of flash-flooding (see Photo Set #12). As well, this research suggests that there has been a notable decrease in snow and glacial mass on the high peaks of the Snow Mountains within the First Bend of the Yangtze. This is apparent in Photo Set #19, where the area occupied by glaciers and snow has decreased from 3.61% of the photo area in the historic photograph to 1.20% in the photograph taken in 2008.

In this chapter, I used both my photo analysis and my literature review to determine the notable landscape changes that have occurred over the past century within the First Bend of the Yangtze. I used Photo Set #19, Photo Set #16, and Photo Set #3 to introduce the reader to the notable landscape changes that have occurred in this area. I use the results from all of the 22 photo sets analyzed to discuss the drivers of landscape changes, as well as their effect on the ecological landscape in Chapter 5.

5.0 <u>Discussion and Conclusions</u>

5.1 Introduction

Chapter 4 provided the results of my rephotography study and vegetation sampling within the First Bend of the Yangtze. In Chapter 5, I first critique the methodology that I used to formulate my results. I discuss the advantages and disadvantages to using qualitative versus quantitative methods of photo analysis. I also discuss the benefits of using Scaled Grid Analysis over using Simple Grid Analysis. In the second part of this chapter, I interpret the results of my rephotography study and vegetation sampling. I relate my results back to my four primary objectives, discussing the drivers for the landscape changes, the effects of these changes on biodiversity and ecosystem health, and use this knowledge to inform contemporary conservation policies. Finally, I discuss future research and final thoughts.

5.2 The Value of Analytical Tools

Within this section, I critique the different methods of analysis used for my photo interpretation. First, I discuss the more qualitative methods of analysis, specifically Presence/Absence and Degrees of Change. I then discuss the different methods of grid analysis that I use for a quantitative understanding of the spatial changes for each landscape classification.

5.2.1 The Qualitative Approach - Presence/Absence and Degrees of Change

Using Presence/Absence and Degrees of Change as a form of qualitative analysis allows for a rapid assessment of the major landscape changes that are evident through each photo set. Using this method, I was able to measure both ordinal and nominal data to establish the major changes quickly. Because these methods allow for such a rapid assessment of the major landscape changes occurring in the area captured in photographs, I decided to use this method to assess additional photographs of the First Bend of the Yangtze that were taken by Robert Moseley as part of his rephotography study for the Yunnan Great Rivers Project. I evaluated the additional photographs to determine whether the landscape changes that I was seeing within my photo pairs appropriately represented the landscape changes within the First Bend of the Yangtze. The qualitative information that I gained through analyzing the additional photo sets was a rapid method that served to strengthen my results: I am able to make generalized statements about the landscape changes that have occurred within the First Bend of the Yangtze over the past century. Because qualitative analysis only allows for ordinal and nominal data to be collected, I added to the photo interpretation and analysis by including quantitative grid analysis to gather both interval and ration data.

5.2.2 The Quantitative Approach – Grid Analysis

As described in Chapter 3, Simple Grid Analysis allows for a quantitative assessment of the change in area occupied by different entities on the plane of the photograph. Simple Grid Analysis allows for a quantitative assessment of the areas occupied by different vegetation communities. A challenge with this form of analysis is that the researcher is only able to define quantitative differences on the plane of the photograph. The distance between the landscape entity being photographed and the feature being photographed is not taken into account. This is a significant issue when the

Figure 5.1 Photo Set #20 with the landscape classifications overlaid. The left and center photograph are identical, taken by Rock in 1923. The photograph on the right was taken by George in 2008. The photograph on the left shows the distribution of landscape classifications when the *Pinus* tree in the foreground is included as part of the warm *Pinus* forest. The middle photograph shows the overlaid landscape classifications with the *Pinus* tree excluded from the analysis. The center photograph offers a more accurate comparison to the distribution of landscape classifications in the 2008 photograph.

Table 5.1 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #20

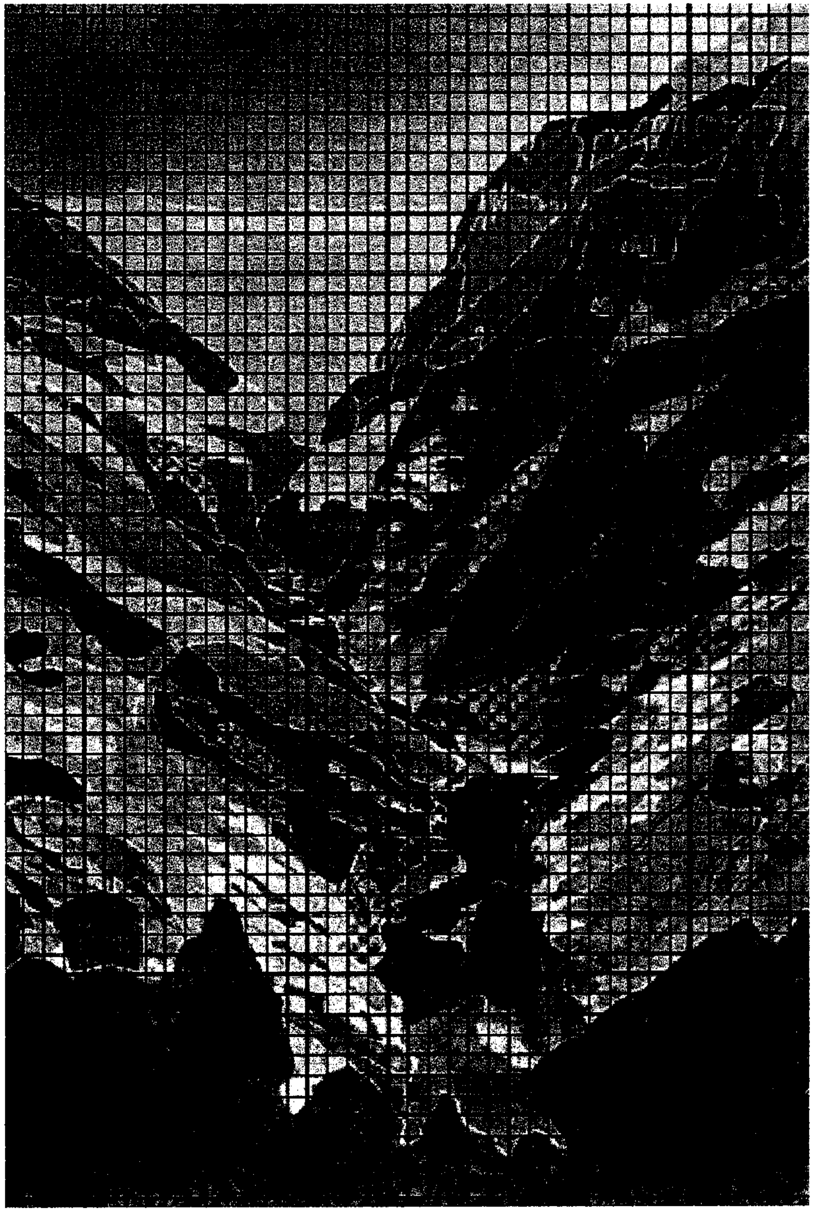
Photo Set # 20- Simple	Rock (1923) Tree		Rock (1923) No Tree		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
[illegible]	0	0.00	0	0.00	4	0.21
[illegible]	0	0.00	0	0.00	10	0.53
[illegible]	201	9.70	259	13.61	210	11.18
[illegible]	31	1.57	42	2.21	68	3.62
[illegible]	62	3.15	61	3.21	68	3.62
[illegible]	16	0.81	17	0.89	5	0.27
[illegible]	10	0.51	10	0.53	0	0.00
[illegible]	111	5.63	276	14.50	32	1.71
[illegible]	0	0.00	0	0.00	338	18.00
[illegible]	595	30.20	116	6.10	0	0.00
[illegible]	210	10.66	329	17.29	318	16.92
[illegible]	469	23.81	484	25.43	567	30.18
[illegible]	275	13.96	309	16.24	259	13.78

photo point is not taken into consideration; therefore, the actual size of each landscape photograph being interpreted shows a drastic variation in distances from each photographed entity to the photo point. Changes in the foreground of the photograph are overrepresented, while changes in the background are not adequately accounted for. **Figure 5.1** (p.138) shows the Simple Grid Analysis of Photo Set #20. I had originally included the *Pinus* tree in the foreground of Rock's 1923 photograph in my count of warm *Pinus* forest; however, when looking at the percentage area occupied by each vegetation community, including the *Pinus* tree as part of the warm *Pinus* forest greatly misrepresented the landscape seen within the photograph. I chose to redefine the vegetation communities within the photograph to exclude the *Pinus* tree and account for the vegetation communities that I suspected to be present behind it. **Table 5.1** (p.139) shows the difference in landscape values between including the *Pinus* tree in the calculation versus removing it from the landscape. Where warm *Pinus* forest occupied 30.20% of the photo area when the tree was included in the analysis, it only occupied 6.10% of the photo area when the pine tree was not included in the Simple Grid Analysis.

Vegetation changes in the foreground of the landscape photographs proved to be a reoccurring problem throughout conducting Simple Grid Analysis on the photo sets. The most challenging photo pair proved to be Photo Set #21 (p. 141). Although the photograph taken by Rock in 1923 offers a clear view of the landscape, by 2008, the photo point was entrenched in warm *Pinus* forest, offering little view of the previously photographed landscape. In a more subjective type of photo interpretation, the increase in warm *Pinus* forest in the foreground of the photograph would make it difficult to analyze the landscape classifications occurring in the middle distance and background of the photograph. Using Simple Grid Analysis, the results greatly misrepresented the spatial distribution of vegetation communities in the photographed landscape. As well as having a misleading percentage of warm *Pinus* forest in the landscape classification counts for the photograph taken by me in 2008, there was also a significant amount of the background landscape that could not be classified because of the restricted view. Any interpretation conducted using the values generated by Simple Grid Analysis would not offer a results that accurately described the landscape.

Because Simple Grid Analysis is only able to determine quantitative differences on the plane of the photograph, interval and ratio data can only be established about the

Figure 5.2 Simple grid analysis of Photo Set #21. The photograph on the left was taken by Rock in 1923. The photograph on the right was taken by George in 2008. Note the growth of warm *Pinus* forest in the foreground.



spatial distribution of landscape classification as it relates to the photo area. This causes significant problems when the vegetation in the foreground of the photograph has changed significantly, as it commonly occupies a disproportionate (overrepresented) amount of the photo area and misrepresents the overall change to the landscape. In photographs where only a few different landscape classifications are present, or in photographs where the area of each landscape characteristic on the photograph correlates well with the area that it occupies on the actual landscape, Simple Grid Analysis works well. But, as the complexity of the photograph increases and more landscape classifications are present, photo interpretation and analysis demands a more thorough method to accurately assess landscape change. In these cases, Scaled Grid Analysis should be used as it allows for a quantitative measurement of landscape change and serves as a more accurate method for determining landscape differences between photo pairs. A downfall of this method is that it is so time-consuming to analyze and interpret the photograph using Scaled Grid Analysis.

I use Photo Set #14 (p.143) to explain the differences between the results found using Simple Grid Analysis versus Scaled Grid Analysis. The landscape features that are present in the foreground of landscape photographs are overrepresented in the calculated percentages when analyzed using Simple Grid Analysis. For example, the riverbank vegetation, as well as the planted *Juglans* within agricultural fields, all classified under human-impacted vegetation, occupied 32.85% of the photo area in Moseley's photograph. Using Scaled Grid Analysis on the same photograph, human-impacted vegetation only occupied 3.36% of the landscape area. Because the human-impacted vegetation occupies the foreground of Moseley's photograph, it was overrepresented using Simple Grid

Figure 5.3 Simple versus Scaled Grid Analysis for Photo Set #14. Rock's (1923) photographs are on the left and Moseley's (2003) are on the right. Note the difference between the simple (top) and scaled (bottom) grid analysis.

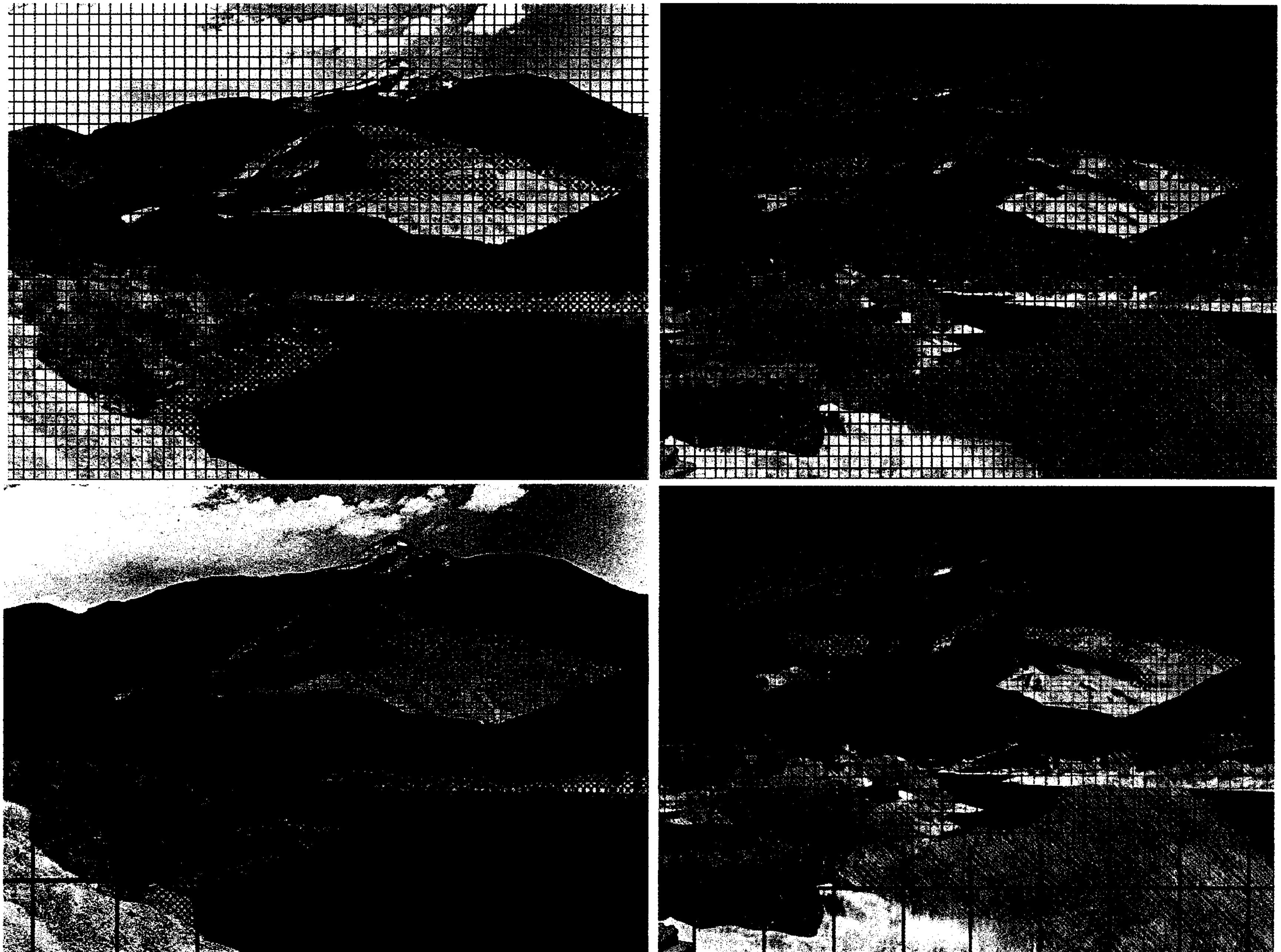


Table 5.2 Simple versus Scaled Grid Analysis for Photo Set #14. Included in this table are the calculated values of Simple Grid Analysis and Scaled Grid Analysis for Rock and Moseley's photographs in Photo Set #14.

Photo Set #14 - Simple	Rock (1923) Simple		Rock (1923) Scaled		Moseley (2003) Simple		Moseley (2003) Scaled	
	#	%	#	%	#	%	#	%
[illegible]								
[illegible]	18	0.96	18	0.37	87	4.67	64	1.26
[illegible]	5	0.27	5	0.10	7	0.38	8	0.16
[illegible]	0	0.00	0	0.00	1	0.05	1	0.02
[illegible]	206	10.96	477	9.87	201	10.79	540	10.61
[illegible]	0	0.00	4	0.08	612	32.85	171	3.36
[illegible]	0	0.00	0	0.00	0	0.00	0	0.00
[illegible]	0	0.00	0	0.00	0	0.00	0	0.00
[illegible]								
[illegible]	38	2.02	229	4.74	46	2.47	150	2.95
[illegible]	13	0.69	89	1.84	0	0.00	60	1.18
[illegible]	88	4.68	76	1.57	16	0.86	0	0.00
[illegible]	472	25.11	72	1.49	69	3.70	55	1.08
[illegible]	6	0.32	105	2.17	0	0.00	14	0.28
[illegible]	11	0.59	125	2.59	10	0.53	272	5.34
[illegible]								
[illegible]	287	15.27	386	7.98	217	11.65	522	10.26
[illegible]	259	13.78	148	3.06	50	2.68	0	0.00
[illegible]	72	3.83	261	5.40	60	3.22	261	5.13
[illegible]	64	3.40	32	0.66	86	4.62	58	1.14
[illegible]	198	10.53	912	18.86	220	11.81	875	17.19
[illegible]	55	2.93	653	13.51	60	3.22	613	12.04
[illegible]	79	4.2	1083	22.40	96	5.15	1247	24.50
[illegible]	9	0.48	160	3.31	25	1.34	179	3.52

Analysis. To contrast, the landscape features that are the furthest from the photo point are underrepresented using Simple Grid Analysis. The subalpine forest occupies only 4.20% of the photo area in Rock's photograph; however, the landscape area occupied by subalpine forest for Rock's photograph using Scaled Grid Analysis is 22.40%. To compare the rest of the landscape classifications for Photo Set #14 using Simple versus Scaled Grid Analysis, consult **Table 5.2.**

Both Simple Grid Analysis and Scaled Grid Analysis measure the area occupied by each landscape classification; however, the area impacted by each landscape classification, specifically land use, does not take into account the effect that each land use will have on the landscape. For example, in a landscape photograph, the area taken up by a road is small in comparison to the total landscape. However, the implications of that road on the landscape could be significant. The construction of a road means that fill is added to secure the river bank, trees are cut down to allow for clearance, erosion occurs where the ground has been leveled out and paved. As well as the construction of the road, it is also important to take into consideration what this road improvement will mean for the surrounding landscape. Improving transportation infrastructure will promote transportation, increasing the amount of cars and the pollution that is associated with them. In addition, improving transportation infrastructure will increase the accessibility to the area and allow for resource extraction, tourism development and an increased population.

When conducting photo analysis and interpretation using repeat photography, I recommend using a combination of qualitative and quantitative methods of analysis, as each method has its advantages and no one method can guarantee the researcher the results of a thorough analysis. When selecting a quantitative method of analysis, I advocate for Scaled Grid Analysis rather than Simple Grid Analysis whenever possible.

5.3 Interpreting Landscape Change

In Chapter 4, I introduced the data that I acquired from – 1) three photo sets of my rephotography study, 2) my literary review, and 3) my fieldwork notes. All of this data pertains to landscape changes along a portion of the Yangtze River. In this section, I provide an interpretation of these changes that suggest, specifically, some drivers of landscape change and implications of these changes on biodiversity and ecosystem health. In addition, I provide some recommendations for contemporary conservation policy based on this research. The landscape changes I comment on have been divided up into four topics: vegetation changes; infrastructural changes; hydrological and geomorphological changes; and general landscape changes. I conclude this section with an overall look at the landscape changes that have occurred in northwestern Yunnan over the past century.

5.3.1 Vegetation Changes

This section provides a discussion of the changes in vegetation that seem to have occurred in the Valley of the Yangtze over the past one hundred years. Based on my data, I discuss arid environments, the distribution of vegetation communities, and traditional land use practices.

5.3.1.1 Arid Environments

As evident through landscape descriptions and photographs from the early 20th century, arid environments have dominated the landscape for over 100 years. This contests the pre-existing belief that arid grassland and arid shrubland vegetation types have resulted from recent deforestation events (Moseley, 2006). In all probability, these dry environments cannot support dense forests. The slopes of the dry valley of the First Bend of the Yangtze have calcareaous or lateritic soils, each with low organic content (Li & Walker, 1986). Because of this combination of aridity and poor soil quality, the dry valleys of the Yangtze River Basin are not able to support forests. Arid grasslands, arid shrublands, and savannahs are prominent vegetation communities in the valleys of this small portion of the Yangtze River Basin because this arid environment does not allow for the growth of forest communities. There does not, therefore, appear to have been much reforestation along this portion of the Yangtze River.

The ecological principle of 'restoring suitable vegetation in the right place' has been suggested for the arid environments in northwestern Yunnan (Ma *et al.,* 2004, p. 83). Where moisture levels are exceptionally low, such as in the arid slopes of sections of the Yangtze River, a successful restoration technique may be to promote the restoration of healthy shrubland and grassland vegetation communities to increase soil stability. This effort would lower cost, as the restoration of these vegetation communities would be of natural process on these landscapes. Restoring a healthy shrubland or grassland to arid lands will lessen erosion and inhibit water loss. Ecological restoration strategies must shift from timber production to ecological improvement.

5.3.1.2 The Distribution of Vegetation Communities

Through comparing the vegetation communities documented by Frank Kingdon-Ward and Heinrich Handel-Mazzetti at the beginning of the twentieth century with those that I encountered during my fieldwork, as well as those detected during my photo analysis, I suggest that the boundaries of vegetation communities appear to be relatively stable, with only a few notable transitions. The tree density has increased within the forested vegetation communities. Several of the areas occupied by woodlands and *Pinus* savannahs in the historic photographs have transformed into either warm *Pinus* forest, or mixed forest (seen in Photo Set #3). This is likely because of policy changes promoting forest growth, as well as a climatic shift to a warmer, moister environment. Based on my analysis, I suggest that government policy, market forces, and global climatic changes have caused the land use and vegetation community changes.

Yunnan is home to a host of different ecosystem types, all with an individual blend of species composition and different distribution patterns. The vegetation communities that house the highest numbers of endemic and endangered species are found on opposite ends of the altitude gradient governing vegetation community distribution in northwestern Yunnan. These are the Evergreen Broadleaf Forest and the Alpine Meadow. Because of the arid environment of the First Bend of the Yangtze, there is little Evergreen Broadleaf Forest. I suspect that, within First Bend of the Yangtze, the only areas that could have grown Evergreen Broadleaf Forest are the river valleys because of their nutrient-rich soils. However, these areas have been cleared for agricultural lands. The alpine environment presents the highest conservation concern.

In many of the lower-altitude environments, the area occupied by forests, both naturally generating, as well as plantations, has increased. This could be the result of natural succession on abandoned agricultural lands. This could also suggests that the abiotic environment – temperature, precipitation levels – is changing. For the alpine environment, the climatic changes suggested by the vegetation changes at lower altitudes could devastate biodiversity levels, as the alpine heaths and meadows have the highest number of endemic and endangered species within any vegetation community in northwestern Yunnan. However, there is little notable change to the alpine environment based on my rephotography study. Photo Set #19 suggests evidence that my support a slight ascent in the location of the treeline.

Warm *Pinus* forest is the dominant vegetation community in many of the mid-altitude forested areas within the First Bend of the Yangtze. Although many argue that the conversion from agricultural lands to forest is beneficial to biodiversity, the forest plantations that are being grown on past agricultural lands, warm *Pinus* forests, are structurally simple, with little biodiversity value. This vegetation community often indicates an area of significant human disturbance and is often degraded by grazing to open woodland (Li and Walker, 1986). Without disturbance, these areas would be Evergreen Broadleaved Forest and Sclerophyllous Forest. Within northwestern Yunnan, reforestation initiatives use *Pinus* species to reforest other vegetation types, rather than trying to cultivate a native forest environment. It must be acknowledged that different forest types support different levels of biodiversity.

5.3.1.3 Traditional Land Use

Traditional land use refers to the human land use practices that have been sustained in northwestern Yunnan for over a century, as evident through the historical photographs and field notes. Handel-Mazzetti and Kingdon-Ward both describe significant human occupation and human impacts on the natural environment, including agricultural lands, grazing pastures, extraction of forest products, and the growth of plantations in the early 1900s. Based on the photo pairs, all of these activities were occurring extensively in the early twentieth century. These traditional land use practices continue through today; however, there has been a noted decline.

Based on the analysis of photo sets, there has been notable abandonment of agricultural lands and an overall decrease in the area occupied by crop fields. The decrease of agricultural land, and the assumed decrease in crop production, has altered the landscape of the First Bend of the Yangtze and directly affected the local rural economy. Ediger and Chen (2006) conducted research on this land use change and discovered that it began in the late 1980s and continues through to today. The earlier conversion activities took place at the household level. Farmers targeted degraded agricultural land to be converted into forested area. In more recent years, afforestation initiatives have been overseen by the government and have been implemented at the district level. The enforced land conversion that has taken place in more recent years has also included agricultural lands with higher levels of productivity (Ediger & Chen, 2006). In turn, there has been a reduction in food production, as a significant amount of the productive farmland is being converted into forest.

Since there is evidence of an increasing human population in the First Bend of the Yangtze over the past century, a decrease in the area occupied by cultivated land indicates a decline in rural self-sufficiency. This land use pattern indicates a labour shift. Many people are choosing to pursue more profitable employment in the cities. This indicates economic development in urban centers within the region. The National Forest Protection Program has also contributed to the declining agricultural lands, giving subsidies to farmers who choose to convert their agricultural lands to forests. The drivers for anthropogenic land use change appear to be China's economic development and government policies.

Willson (2006) explains that many of the old agricultural lands that were present at the beginning of the twentieth century have been turned into pasturelands to promote a more intensified strategy for animal husbandry. Xu and Wilkes (2004) note a steady increase in the numbers of livestock, despite the overall decline in the quality and area occupied by rangelands. Specifically, the alpine rangelands that are commonly used for summer grazing pasture have shown a significant decline in area over the past century. There are several drivers behind this landscape change. First, changing livelihood strategies and the decreasing interest in family farming due to economic incentives in urban centers has served to decrease livestock numbers in alpine rangelands. Many of the high-altitude grasslands are now subject to the process of natural succession because the amount of grazing has decreased, allowing the encroachment of woody species. Grasslands are being transformed to shrublands and then to subalpine forests. The government is restricting the use of alpine meadows for livestock grazing and enforcing strict regulations against burning (Willson, 2006). The restrictions on burning that have been enforced over the past 50 years have undoubtedly impacted vegetation communities, allowing some previously disturbed areas to reforest themselves naturally, becoming woodlands and then forests. Farmers used to burn *Rhododendron* and other woody subalpine species to maintain the area occupied by alpine meadows. In recent years, there has been a noted encroachment of woody species in alpine meadows, causing a significant loss of this vegetation type.

As well as grazing in the alpine meadows, arid grasslands and shrublands are used for grazing at lower altitudes. The traditional nomadic pastoralism that was practiced within northwestern Yunnan has decreased. Pastoralists are no longer willing to seasonally migrate to the higher-altitude grazing pastures. Therefore, instead of only seasonal grazing pasture, arid grassland and shrublands are now used year-round, causing overgrazing and ecosystem degradation, especially with increasing livestock numbers. To protect these lower ecosystems, grazing in alpine pastures should be encouraged. In addition, grazing in this higher ecosystem prevents the encroachment of woody plants, allowing the preservation of this biodiverse environment. All grazing must be monitored and, where necessary, restricted.

Based on the landscape transitions documented through photo pairs, it appears that forested area has increased over the past 100 years. The reforestation that has occurred within the First Bend of the Yangtze could have been caused by several factors. Land use policies have also led to a significant decline in cultivation on hill slopes, as government subsidies have been created to promote reforestation in these areas. As mentioned in Chapter 2, the Sloping Land Conversion Program (SLCP), also known as 'Grain for Green' is a program developed in China to encourage large-scale afforestation by giving subsidies to farmers who convert agricultural lands that occur on a slope greater than 25 degrees to forest plantations. These initiatives have had a significant impact on the land use and land cover changes that have occurred in northwestern Yunnan in recent years. These government-sponsored reforestation initiatives have been met by speculation as a significant amount of area that farmers are attempting to reforest does not offer the abiotic conditions, primarily temperature and the availability of water, required to meet the needs of a forest vegetation community. In addition, some of the forested area near villages continues to be used for timber for construction and fuelwood. Yet, despite the increasing population, the forest area and tree density seems to have increased over the past 100 years. It appears that village members are using forest resources sustainably.

This research suggests that deforestation due to agricultural expansion is not a new issue and deforestation due to agricultural expansion has decreased significantly over the past century as agricultural lands are converted back into forest. Croplands are actually decreasing in area and clearing of native vegetation for agricultural lands is not a threat to biodiversity. Finally, there is a misconception that the arid grasslands and shrublands that are prominent at the lower altitudes of the river slopes are a degraded landscape that was deforested and now, because of erosion and poor soil quality, a new forest cannot regenerate. Based on photographic evidence, these vegetation communities have existed at the lower altitudes of the Yangtze River Basin for over a century and the environment that houses this vegetation type cannot support a forest environment. The local human impacts that have been identified in the past as being biodiversity threats seem to show only a minor impact on the biodiversity levels in northwestern Yunnan.

Reforestation initiatives should also take into account the spatial pattern of vegetation communities. Habitat fragmentation is a significant factor limiting the distribution of both floral and faunal species. Forest fragmentation will hinder biodiversity levels because it will not allow the spread of species naturally occurring in that community through corridors and it will also increase the occurrence of edge environments that commonly encourages the growth of opportunistic species. It is important to point out that, although repeat photography can address forest cover and density and, based on the vegetation community identified through using indicator species, can suggest what biodiversity is present, ecosystem health cannot be fully addressed. Many of the activities that alter the species composition and threaten biodiversity levels within forest communities cannot be seen through the canopy. Moseley gives the example of low-magnitude selective tree felling (Moseley, 2006). More intensive ground sampling is required to better assess the ecosystem health and biodiversity levels in northwestern Yunnan.

Many of the reforestation initiatives that are currently being executed in northwestern Yunnan use fast growing species, such as *Pinus densata*. The priority of these conversion projects cannot be to promote biodiversity, as policy is promoting the growth of forest plantations, rather than of healthy forest ecosystems. The World Agroforestry Center (ICRAF) offers international training sessions on nursery development and silviculture. This agency is composed of staff from a variety of organization types from all over the world. ICRAF has collaborated with Yunnan University to support local training workshops concerning forest rehabilitation and the development of local management plans for forest environments (Weyerhaeuser and Kahrl, 2006). This training helps local people who are involved in land use planning to choose suitable sites for agroforesty through identifying appropriate habitats and species. This training also teaches land use planners to identify fragile sites that require environmental protection

Agroforestry can be used as a method of employment in northwestern Yunnan. As well as providing jobs and urging environmental education, agroforestry is a method of providing economic opportunities to farmers and enhancing ecosystem services. Increasing forest cover on exposed soils can mitigate erosion and flooding problems, enhance slope stability and increase soil quality. Further, if agroforestry programs are thoroughly researched and properly governed, they will be able to aid in environmental conservation and biodiversity protection since agroforests can provide timber for construction and fuelwood rather than degrading more native forests to meet the demands for forest products.

5.3.2 Infrastructural Development

The infrastructural development in northwestern Yunnan has grown significantly in the past couple of decades, especially as northwestern Yunnan becomes a noted international tourist destination. Even since Robert Moseley took his photographs in 2003, there have been significant changes to the commercial and power grid infrastructure present in northwestern Yunnan. Specifically, guesthouses, restaurants, high-voltage power lines, and better roads are consequences of the economic development in the region. In this section, I highlight these types of land use transitions, talking specifically about road infrastructural development, the development of hydro infrastructure, and tourism development within the First Bend of the Yangtze.

Road infrastructure has increased greatly over the past century. Dirt pathways were prominent in the early 1900s bordering the Yangtze River. These pathways were used as passage ways for people on foot or on animal. The recent photographs show that there has been significant development of transportation infrastructure. Two-lane paved roadways border both sides of the Yangtze River within most regions of the First Bend of the Yangtze. This is an engineering feat, considering the steep slopes of many of the river banks in this area.

However, the creation and expansion of road infrastructure is known to have a significant impact on the ecology of the landscape. Habitat fragmentation is a primary ecological consequence of the expansion of road networks (Liu *et al.*, 2008). In addition, the construction of roads disturbed the natural ecosystem, removing the original land cover and creating an edge habitat, an environment not suitable to many of the plants that formally grew in that environment. The development of road infrastructure is known to alter the landscape pattern, changing the succession of ecosystem elements within the area of disturbance.

Finally, the development of transportation infrastructure allows for easy access for humans. China is rapidly constructing new roads (Liu *et al.*, 2008). As China continues to develop, many major roadways have been constructed in Yunnan Province to help connect western China to Southeast Asia. As highways account for more than 93% of the total transportation routes in Yunnan, road networks may be one of the largest single factors influencing ecosystems (Liu *et al.*, 2008).

Power infrastructure, while absent in the historical photographs, is now well developed within the First Bend of the Yangtze. Even in the period between Moseley's photographs, taken in 2003, and my own, taken in 2008, there has been extensive infrastructural development, including hydro towers, power lines, and power generation stations. These can be seen in Photo Set #3 and Photo Set #14. With this growth in infrastructure comes an increase in environmental disturbance. For instance, forests have been cleared for power lines. An example of this is in the top left corner of my photograph in Photo Set #16.

The consumption of electrical energy in China is increasing, used not only by the industrial sector, but also at the household level. Within China, industry accounts for 71% of the demand for power (Brown *et al.,* 2008). However, in recent years there has been a significant increase in personal incomes in China, even in rural areas (Brown *et al.*, 2008). With higher personal incomes, the Chinese population is beginning to demand more consumer goods, such as televisions, refrigerators, and microwaves, all increasing the demand for electricity.

Within China, there are a variety of sources for electricity generation. At present, China relies on coal as their primary source for power generation, producing 78% of China's power (Rosen & Houser, 2007). Sixteen percent of China's electricity is generated through hydro. With the increasing demand for electricity generation, the amount of hydropower being produced is guaranteed to increase. There are plans to significantly increase the amount of hydropower infrastructure to generate 45% of China's required electricity (Brown *et al.,* 2008). China is known to have the greatest potential for hydropower development in the world (Brown *et al.,* 2008). On the Yangtze River, downstream from the First Bend of the Yangtze, the Three Gorges Dam has a total capacity of 18, 200 MW. It is the largest dam in the world. There is also a series of dams planned for the Jinsha River, upstream from the First Bend of the Yangtze, that will have the total capacity of 38, 500 MW.

The development of hydroelectric dams is known to have environmental and ecological consequences. Further development of dams on the Yangtze River will undoubtedly cause ecological degradation, as water levels change, and patterns of flooding and aridity begin to occur. Dam development will also cause socioeconomic impacts, including food insecurity, loss of cultural tradition, and depression among those who have to be displaced (Brown *et al.,* 2008). Increasing power generation within China will cause environmental and socioeconomic consequences within the First Bend of the Yangtze. The effects are already beginning to be seen through the landscape changes that have occurred between photo pairs.

In January 1999, a statement was issued by Yunnan's provincial government, identifying almost 60 percent of the province's counties as 'poor' and over 3.5 million of a total population of 44 million as living below the poverty line. A response to this statistic was a plan to address the need for economic opportunity through tourism development. The natural environments, as well as the diverse cultural identities found in the 26 minority groups that make up 60% of the province's population, have been used as resources for tourism development.

Tourism was virtually non-existent in China 20 years ago, but, since that time, tourism has skyrocketed to one of the country's most prominent industries. In 1978, Hua Guofeng, the leader of the Communist Party, began promoting tourism incentives, promoting the development of the sector. In 1978, 1.81 million tourists visited China; almost 90% of them were from Hong Kong. By the year 2000, more than 750 million domestic tourists and 60 million international visitors were reported annually. The total annual revenue from tourism in China in the year 2000 equaled 41.4 billion US dollars and amounted to 4.3% of China's gross national product (Sofield & Li, 2003).

Yunnan is heavily marketed as an 'ecotourism' destination; however, the Chinese perception of 'natural' greatly differs from that accepted in the Western paradigm of ecotourism. The nature-based tourism that is currently in operation within Yunnan Province is typically characterized by an absence of natural heritage education, as well as environmental sustainability information. Economic incentives drive the development of the tourism industry within Yunnan (Sofield & Li, 2003). Therefore, any tourism operation that has the venue will shift to mass tourism as opposed to ecotourism, which typically is planned for areas that have lower levels of tourists. Because of the growing popularity of 'ecotourism', it is important that stipulations and guidelines for advertising tourism as eco-friendly be put in place.

Tourism exerts a significant amount of pressure on ecosystem health and biodiversity. Because tourism creates significant income, tourism development for economic development takes precedent over environmental conservation. Within China, it is accepted that any natural landscape feature or wilderness area that is turned into an attraction for tourists will succumb to anthropogenic 'upgrades' that will alter the natural landscape. Infrastructural improvements, including road access, hydro, and septic systems, as well as facilities for recreation and tourism, such as observation towers, visitor centers, and park gatehouses, as well as supplementary infrastructural improvements, including hotels, guest houses, restaurants, and markets, will be developed to fit the tourists' need of 'comfort in nature'. Continually, structural improvements will be made that offer a greater convenience to humans, including more frequent automobile transportation, concrete paths, and resorts will be permitted within reserves, cable cars will be built.

Through my rephotography study, I indentified several infrastructural and landscape changes that are likely to be the result of an increasing tourism sector. First, in many of the more popular tourist destinations within the First Bend of the Yangtze, the poor quality high-altitude agricultural land is now being abandoned because the local farmers are seeking the economic opportunity created through increasing tourism in the area. Many farmers are choosing to raise mules to transport tourists to scenic lookouts. I saw this at the entrance to Tiger Leaping Gorge. There are also several new guest houses being built and upgraded to meet the increasing demand for tourist lodging along the hiking trail that looks over Tiger Leaping Gorge. As mentioned in Chapter 4, Photo Set #19 shows the presence of a tourist area within Tiger Leaping Gorge. This large parking area for tour buses offers many services, including tourist information centers, variety stores, and restaurants, all catering to the needs of the tourists.

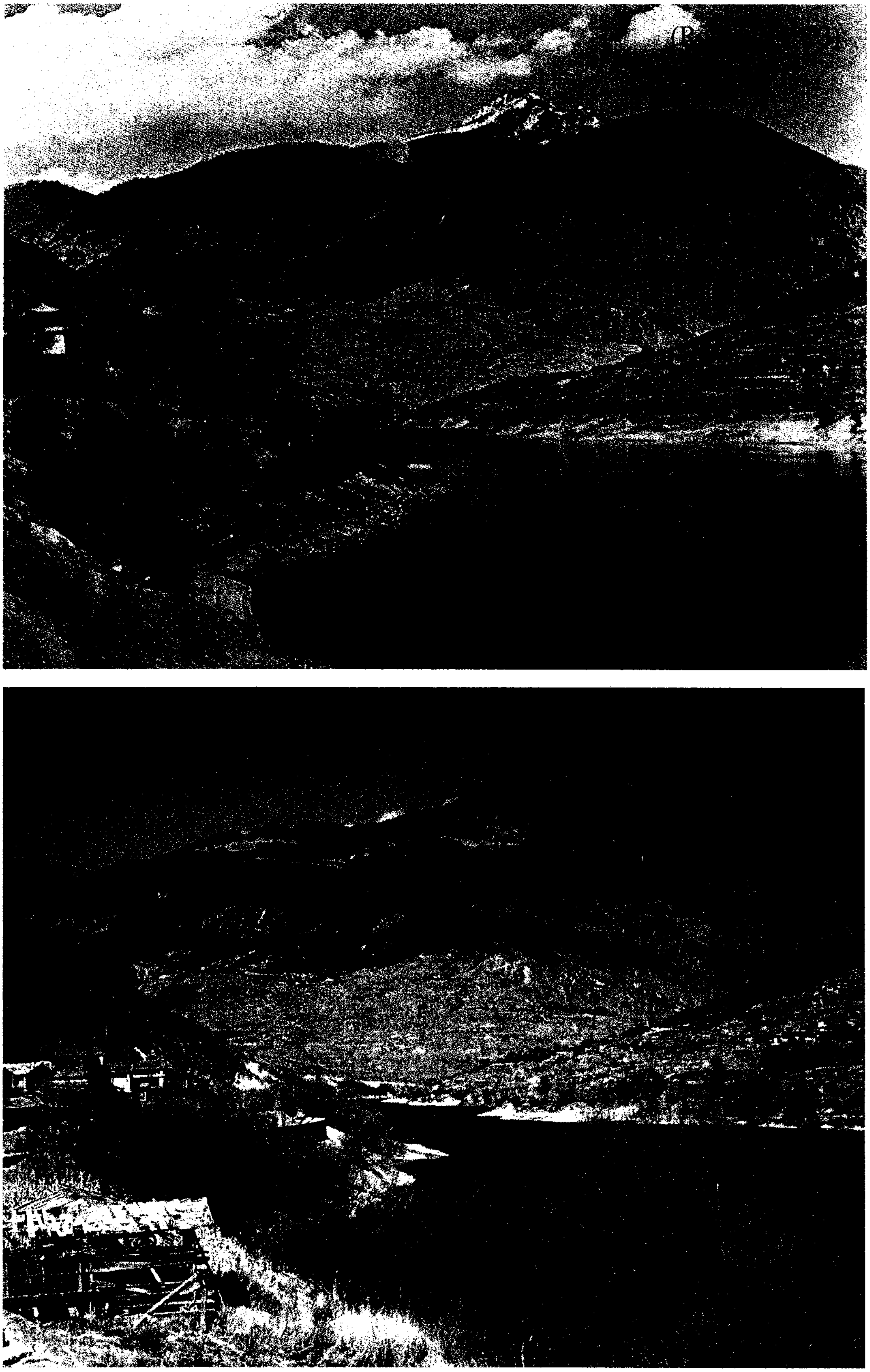
Tourism development poses a particular threat to the alpine environment within the First Bend of the Yangtze. Yulong Snow Mountain, which contains a variety of high-altitude vegetation communities, including temperate coniferous forest, alpine meadow, scree and cold scrub habitats, is being degraded by massive tourism development, despite being enclosed within a nature reserve since 1984. The Qianhu Mountains - in the northwestern section of my study area, near Zhongdian (Shangri-La) - have been identified as being a significant area for endangered species and endemic species richness; however, they were subject to intensive deforestation caused by commercial logging in the 1980s and the 1990s and, although this area was designated as a state park, it has recently been leased to a private company for mass tourism development. Lijiang, a designated UNESCO world heritage site, is a hub for both national and international tourism, but it seems to be suffering from overdevelopment. Within this region, there is a concern about who is profiting from the tourism development. Those who were originally targeted in 1999 by Yunnan's government seem to have been driven out by foreign investors. The massive tourism development within northwestern Yunnan seems to have further marginalized those living below the poverty line.

5.3.3 Regional Hydrology and Temperature

Over the past century, there have been noted oscillations in annual temperatures in northwestern Yunnan, with high summer temperatures occurring in the 1930s-1950s, and 1990-present. Notable seasonal lows occurred from 1900-1920, and again from 1965-1980. The advance and retreat of monsoonal-temperate glaciers are largely controlled by oscillations in summer temperature. The colder summer temperatures that were witnessed in 1900-1920 are consistent with recorded glacial advances, or stability. The periods of high summer temperatures (1930-1950 and 1990-present) correlate with glacial retreat. The 1930s-1950s have been cited by Fan *et al.* (2009) as being the warmest periods in the past few centuries. However, Fan *et al.* (2009) suggest that the most drastic recorded increase in annual temperature has occurred in northwestern Yunnan since 1980; therefore, the effects of the recent climatic changes have yet to be seen in changing vegetation distributions.

During the early part of the twentieth century, Kingdon-Ward discusses the glaciers along the First Bend of the Yangtze as being in an advanced state of dissolution. Fan *et al.* (2009) claim that during this period, the temperature allowed for glacial advancement in this area. As shown in **Figure 5.4** (p. 161), the glacial masses and snow have greatly decreased over the past century. Where Haba Shan shows a notable amount of snow in the historical photograph, there is no snow present in the photograph taken in 2003 during the same time of year. This does suggest that there has been a warming trend over the past century.

Figure 5.4 Photo Set #14, Haba Shan. The top photograph was taken by Rock in 1923, the bottom photograph was taken by Moseley in 2003. Notice the decrease in glacial mass and snow on the peak of Haba Shan.



Climatic analysis using tree-ring densities has determined that, within the past 50 years, the regional temperature within northwestern Yunnan has increased significantly. This warming trend has primarily been attributed to the increasing minimum temperatures, rather than a significant increase in maximum temperatures (Fan *et al.*, 2009). This is a significant factor governing vegetation distribution, as winter temperature is known to limit the poleward/upward distribution of tree species and vegetation communities (Jing-Yun *et al.*, 1996). Since 1980, there has been a notable decrease in the diurnal temperature ranges, which Fan *et al.* (2009) have attributed to an increase in cloud cover. This assumes more moisture in the area, as well as an increase in precipitation. It also encourages less evaporation.

As well as temperature, the availability of water is a primary factor determining the distribution of vegetation communities. Within northwestern Yunnan, monsoon dynamics are viewed as a major factor governing water availability. The Tibetan Plateau plays a vital role in determining regional climate. The westerly jet stream is pushed north of the Tibetan Plateau. The southern side of the Himalayan range is exposed to the southwestern monsoon and the tropical cyclones that originate on the Indian Ocean during the summer season. In the winter, northwestern Yunnan is protected from the southward invasion of the Siberian cold air mass by the Tibetan Plateau.

In recent years, global circulation models have noted an increase in the summer monsoon precipitation in northwestern Yunnan. This trend is predicted to continue. High temperature during the growing season is known to increase levels of evapotranspiration and decrease the moisture available in the soil. The most significant period of drought recorded in the past few centuries occurred during 1910-1925. There was also a period of drought from 1960-1990, especially in 1983-1986. From 1990 to present, the spring climate has been moist, but still within the natural environmental variations that have occurred over the past few centuries (Fan *et al.,* 2008b).

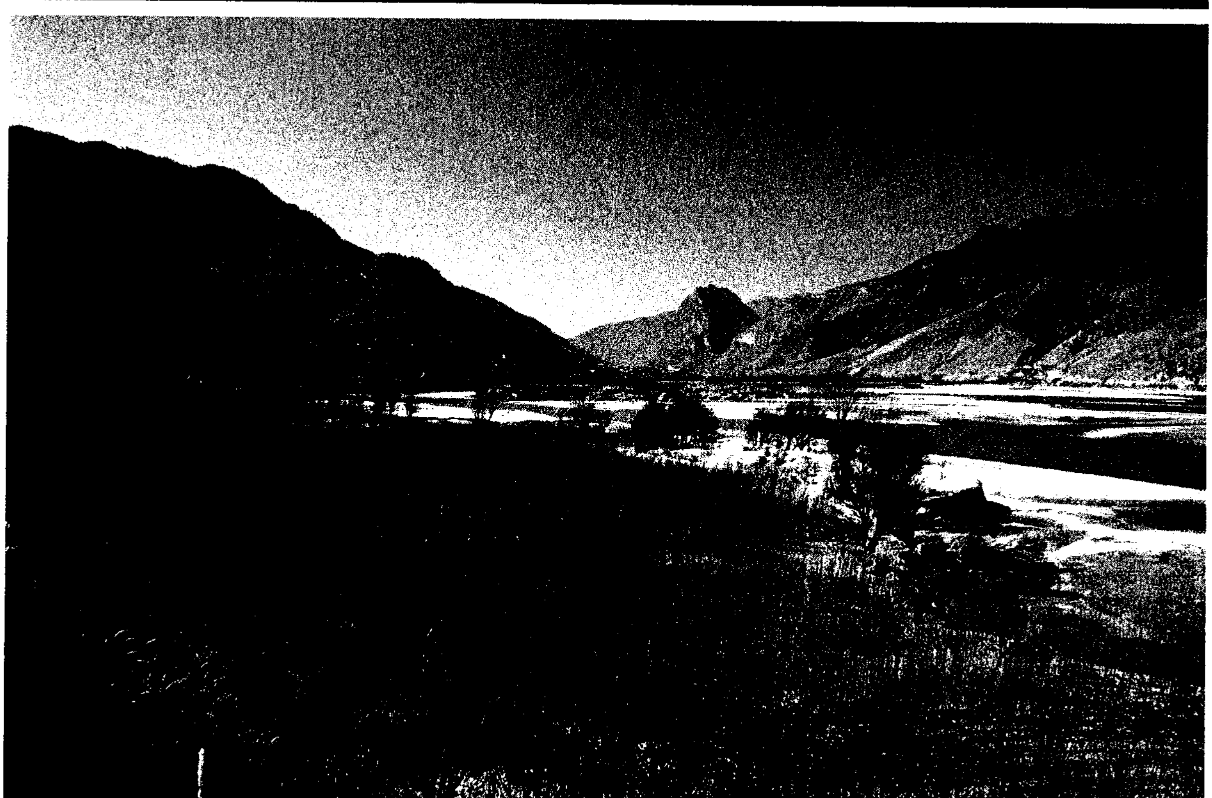
Evidence of increasing water availability on the slopes of the Yangtze River within the First Bend of the Yangtze is apparent through the increasing tree density and changes in the distribution of vegetation communities. Climatic analysis using tree ring densities suggests that water should have been less available in the historical photographs than in the photographs taken in the early 21st century; however, the decreased glacial masses, as well as the water levels in the Yangtze River suggest that there is less water available or, if there is more water available, it has been diverted for human uses. **Figure 5.5** (p.164) displays Photo Set #12. It appears that the water levels in this area may be lower now than they were a century ago, as indicated by the vegetation growth on river geomorphology that appears to have been seasonally submerged in the past, hindering the growth of vegetation. This could also indicate a reduction of flash flooding, more hydrological stability or damming.

5.4 Summary of Findings

As previously mentioned in Chapter 2, 10 minority groups occupy the high-altitude environment of northwestern Yunnan. The levels of poverty are high and there are a variety of risks associated with the high-altitude rural communities. While many initiatives have started in northwestern Yunnan to conserve the natural environment and preserve biodiversity, little priority has been put on the rights of the local people and the value of their traditional customs. Many of the people living in the high-altitude environments of northwestern Yunnan are agropastoralists, growing crops while supporting livestock. Because a large percentage of the rangelands that are occupied by the agropastoralists of

Figure 5.5 Photo Set #12, the First Bend of the Yangtze. The top photograph was taken by Rock in 1923. The bottom photograph was retaken by Moseley in 2003.

(Rock, J., 1923)



northwestern Yunnan are forest rangelands, agropastoralists have used forest products for building and for fodder. As well, they have harvested non-timber forest products for cash income.

However, contemporary resource management policies have banned commercial logging, eliminating that income source. In addition, the Farmland Slope Conversion Project has reduced agricultural and grazing lands, as the saplings planted have to be protected. These policies have threatened the livelihoods of the populations in peripheral areas who are living traditional subsistence lifestyles. In recent years, programs have been developed to help with the economic transition that is occurring in northwestern Yunnan, at present. These include initiatives such as the CBIK's 'Enhancing the Livelihoods of Agropastoralists in NW Yunnan' project, that have been started in northwestern Yunnan to educate and arm local villagers and stakeholders with the tools necessary to develop the appropriate innovations to maintain traditional agropastoralist lifestyles during this period of economic transition.

It should be noted that biosphere reserves offer a useful model for conservation management in areas where traditional groups are living in an ecologically sensitive area. A protected 'core' area is surrounded by a 'buffer zone' and finally by an area of 'transition'. The core area is founded on a preservationist approach, prohibiting all human occupation except for scientific research. Within the 'buffer zone', activities that do not conflict with the 'core' area are allowed (Wenjun *et al.,* 1998). These include research, education, training recreation and tourism. Finally, development activities are permitted within the transition area. Employing a buffer zone to protected areas can aid the biological conservation of the 'core' area, as well as allow a form of compensation to the local inhabitant for the economic losses that they will suffer from being prohibited to use the natural resources that exist within the 'core' area. The structure of a biosphere reserve exhibits an attempt to promote cooperation with local communities to promote biological conservation, while, at the same time, allowing a source of economic opportunity.

It is increasingly acknowledged that biodiversity conservation, as well as social and economic development must be addressed while forming contemporary conservation policy. Within developing countries, such as China, economic opportunities heavily outweigh environmental concern, causing additional pressure from stakeholders. It is imperative that the integrity of conservation policy be maintained and that it not be masked by economic interests.

Overall, the local population does not seem to play a large role in the land use transitions that have occurred over the past century. The major drivers of landscape changes appear to be less localized. Market forces and government policies promoting economic opportunities and massive infrastructural development has greatly altered the landscape of northwestern Yunnan in recent history. As well, programs promoting afforestation have increased the amount of forested area while reducing the amount of agricultural lands. Climatic changes seem to be the cause of variation in the spatial distribution of vegetation communities on the upper slopes of the Yangtze River Basin. An increase in the available water, caused by noted changes in monsoon dynamics, has caused an increase in forest density and has aided in the conversion of woodland areas to forests.

From the biodiversity perspective, the decrease in agricultural lands and reforestation initiatives can be seen as a positive land use transition. There are other human impacts, however, that cannot be looked on with such environmental optimism. The infrastructural development in northwestern Yunnan has grown significantly in the past couple of decades, especially as Yunnan becomes a noted international tourist destination.

Even since Robert Moseley took his photographs in 2003, there have been significant changes to the commercial and power grid infrastructure present in northwestern Yunnan. Specifically, guesthouses, restaurants, high-voltage power lines, and better roads are consequences of the economic development in the region. Butain *et al.* (2007) declare that, although traditional landscape uses seem to have been sustained for thousands of years, the vegetation communities are now presenting symptoms of degradation. Butaine *et al.* (2007), among others (Xu and Wilkes, 2004), attribute these changes to external forces, including economic development, an increasing international market, a transition away from subsistence lifestyles, and mass tourism development.

It is imperative that conservation policy makers should be skeptical of assumptions that have been made regarding the past ecological landscapes and the drivers of landscape change. It is important that policy makers demand data-driven threat assessments before making policy decisions. Further research needs to be conducted to gather baseline information concerning the current ecological landscape of northwestern Yunnan. There is also significant need to establish a monitoring network from this baseline information to immediately identify ecosystem changes and threats to ecosystem health and biodiversity in this region. Interdisciplinary research must be conducted to fully address the complexity of this conservation issue.

Working with the biosphere reserve model, conservation areas can be established in northwestern Yunnan that target native ecosystems with considerable species richness and a high level of endemic and endangered species. Buffer zones can be established that offer agropastoralists an area to carry out traditional practices without the threat of being outcompeted or restricted. Finally, establishing these types of reserves will serve to check the development of tourism infrastructure within fragile ecosystems, as they will be restricted to the transition area.

5.5 Future Research

I hope that this thesis allows the reader to comprehend the urgent need for baseline research, environmental monitoring, and environmental governance in northwestern Yunnan. Detailed data about the current ecological landscape is required to adequately assess future environmental changes. Because mountain environments are susceptible to environmental change, monitoring networks should be established to ensure that conservation policies are properly targeted and effective. Funding must be allocated to research and education to improve our understanding of the natural environment, specifically ecosystem dynamics in response to climate change, and innovation to mitigate future threats to ecosystem health.

My repeat photography study looked strictly at the Yangtze River Basin around the First Bend of the Yangtze. Thanks to the botanical explorers who traveled to Yunnan in the early twentieth century, there are writings and photo documentation of many historical landscapes within northwestern Yunnan, and the surrounding area. I recommend that repeat photography research continues in northwestern Yunnan because of the valuable information that can be discovered about past landscapes, the rates of landscape change, and patterns of disturbance. Because of the biodiversity present in these ecosystems, I suggest further rephotography work in northwestern Yunnan focus on either the alpine environment, or the lower-altitude jungles. There are historical resources available to build these studies.

Although my research suggests that there has been very little floral biodiversity loss within the First Bend of the Yangtze, severe loss of faunal diversity within northwestern Yunnan has been identified (Andrews, 1918; Yang *et al.*, 2004). Research on historical ranges of extirpated species and the causes of their disappearance, as well as possible methods of reintroduction into the area would be useful research that would serve to restore the natural environment.

Finally, I would like to encourage the establishment of conservation values specific to each vegetation community and ecosystem type. These values need to sum the importance of conserving each vegetation community, based on the area occupied by that community, the fragility of the ecosystem, the number of endemic and endangered species within that ecosystem, etc. These values would help to determine the threats to biodiversity when spatial changes of vegetation communities do occur, as well as aid in the formation of conservation strategies. As well as conservation values, I would like to advocate for the development of disturbance values. Every human disturbance affects the natural ecosystem in a series of ways; I would like a way to quantify the implications that each type disturbance has on the natural environment, based on the area that it occupies.

5.6 Concluding Thoughts

There are two main points that I would like to highlight within my conclusions: first, I would like to address the need for interdisciplinary research to inform conservation policy; and further, I would like to emphasize the value of collaboration between stakeholders in the process of conservation policy formation.

I feel that this repeat photography study allowed me to The importance of achieving an *interdisciplinary* understanding of the ecological landscape changes that occurred in northwestern Yunnan over the past 100 years resonated throughout my research. Environmental science is defined as an *interdisciplinary* study of environmental systems, how these systems operate and how people interact with them. Issues concerning economics, politics, security, and meeting human needs are all linked to responsible resource management and environmental planning. The reality is that relatively little is known about the complexity of environmental systems. A collaborative initiative, uniting minds from different backgrounds and offering different perspectives and sources of knowledge, must be accomplished to successfully achieve environmental governance, specifically with regards to biodiversity protection and ecosystem health research.

It is imperative that responsible routes for sustainable development and resource management in peripheral areas be created and administered to better address the conservation of fragile ecosystems while ensuring that the needs of the human population are also met. Specifically, adaptive co-management should be highlighted as a method of including local populations in conservation efforts as well as honouring their traditional ecological practices. Ensuring collaboration between stakeholders, practitioners and researchers to identify and monitor environmental issues is imperative for the success of conservation initiatives. A coordinated effort through participatory monitoring and evaluation by stakeholders and an open forum for engagement and priority setting is the most likely way to achieve effective and efficient conservation policy while promoting sustainable development.

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APPENDIX A:
PHOTO SETS
THE FIRST BEND OF THE YANGTZE

This appendix offers the reader a source of the photographs that I used to conduct my rephotography study of the First Bend of the Yangtze. I used 22 photo sets to conduct my analysis. Joseph Rock took the original photographs used for this landscape analysis in 1923. I retook ten of his photographs in 2008. I also used photographs retaken by Robert Moseley of the Nature Conservancy as part of the Yunnan Great Rivers Project. These photographs were taken from 2003-2005. Below is a map showing the photo points. Each photo set is numbered from 1 to 22, starting at the furthest upstream location (top left) and heading downstream. The photographs taken by Rock (1923) and myself (2008) are noted in light blue, those photographs taken by Rock and Moseley (2003) are portrayed in medium blue, and those photographs taken by Rock (1923) and then retaken by both Moseley (2003) and myself (2008) are shown in dark blue. For a larger version of this figure, consult **Figure 4.1** (p. 74).

Figure A.1 A map of the First Bend of the Yangtze showing the location of each photo point. All photographs were originally taken by Joseph Rock in 1923. The photographs retaken by George (2008) are shown in light blue, retaken by Moseley (2003) are noted in medium blue, and those photographs retaken by both are evident in dark blue.

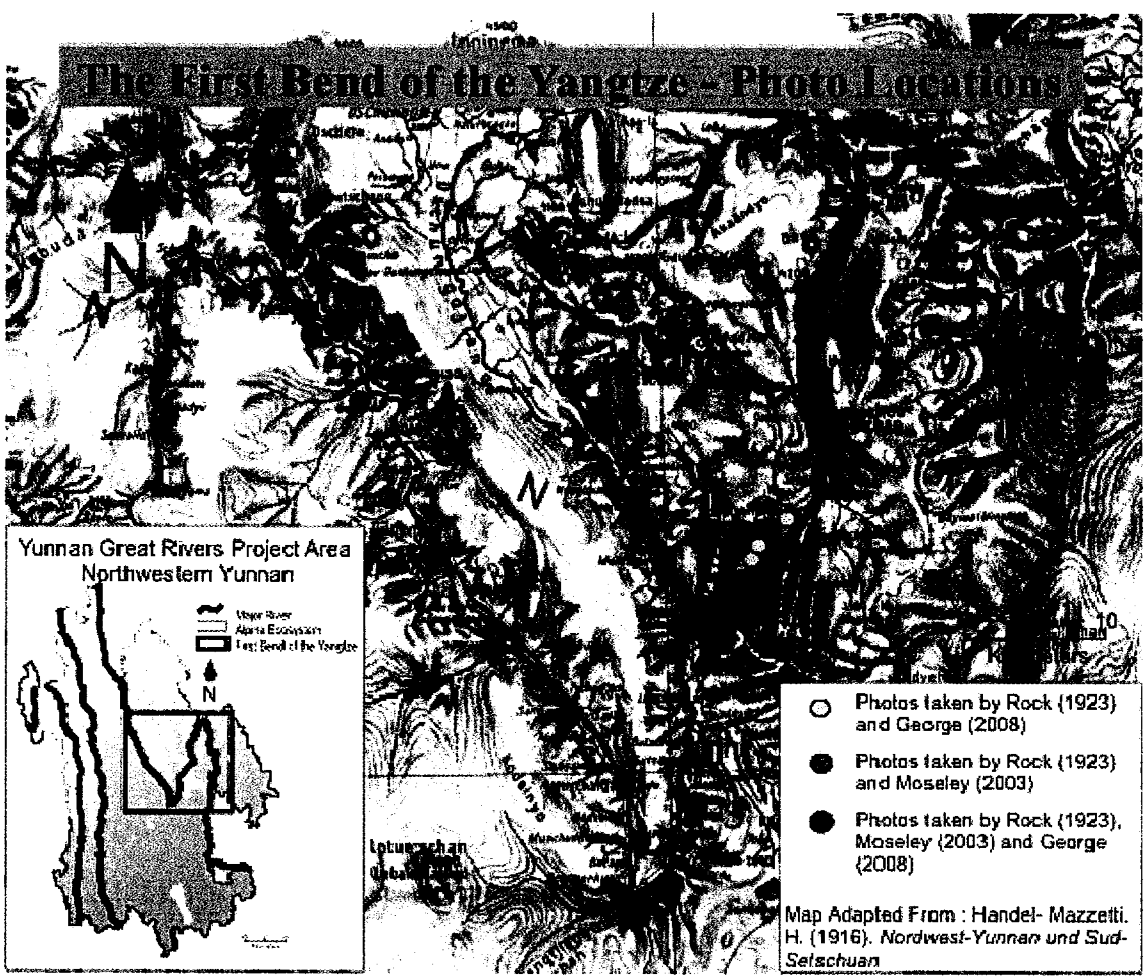
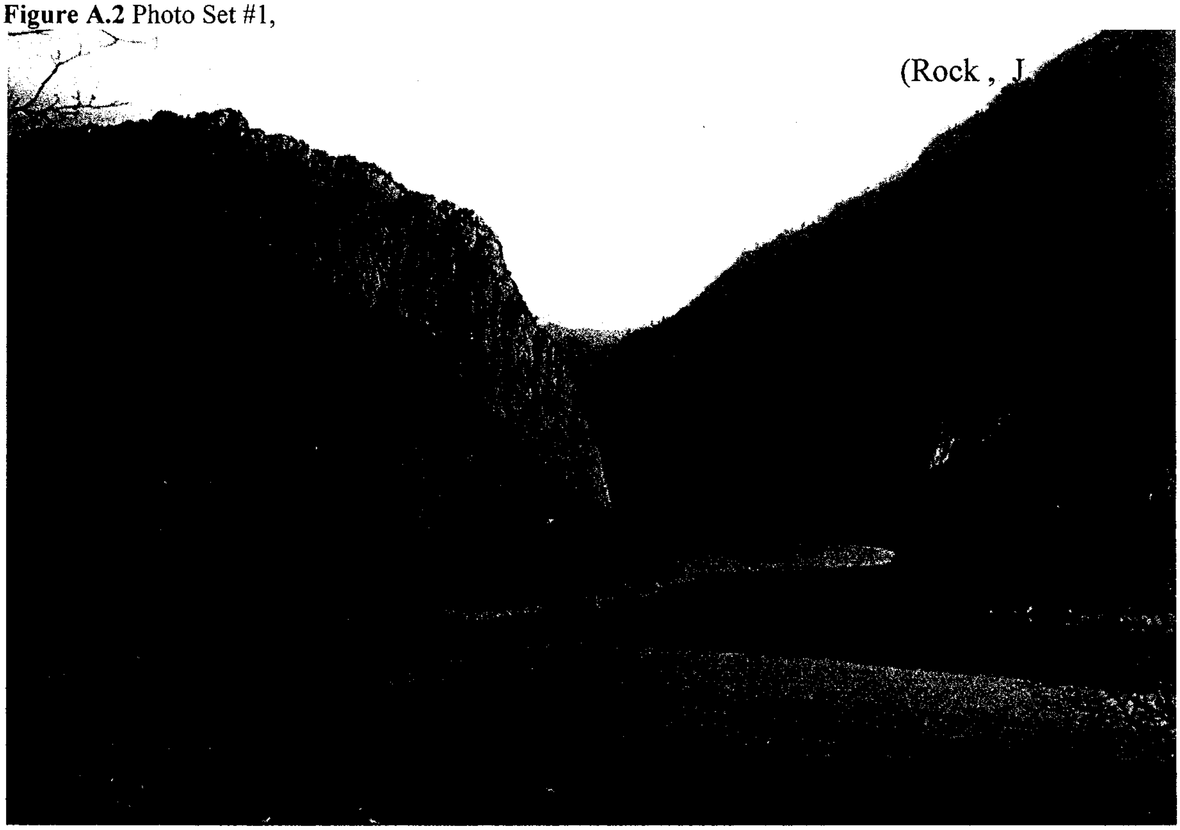
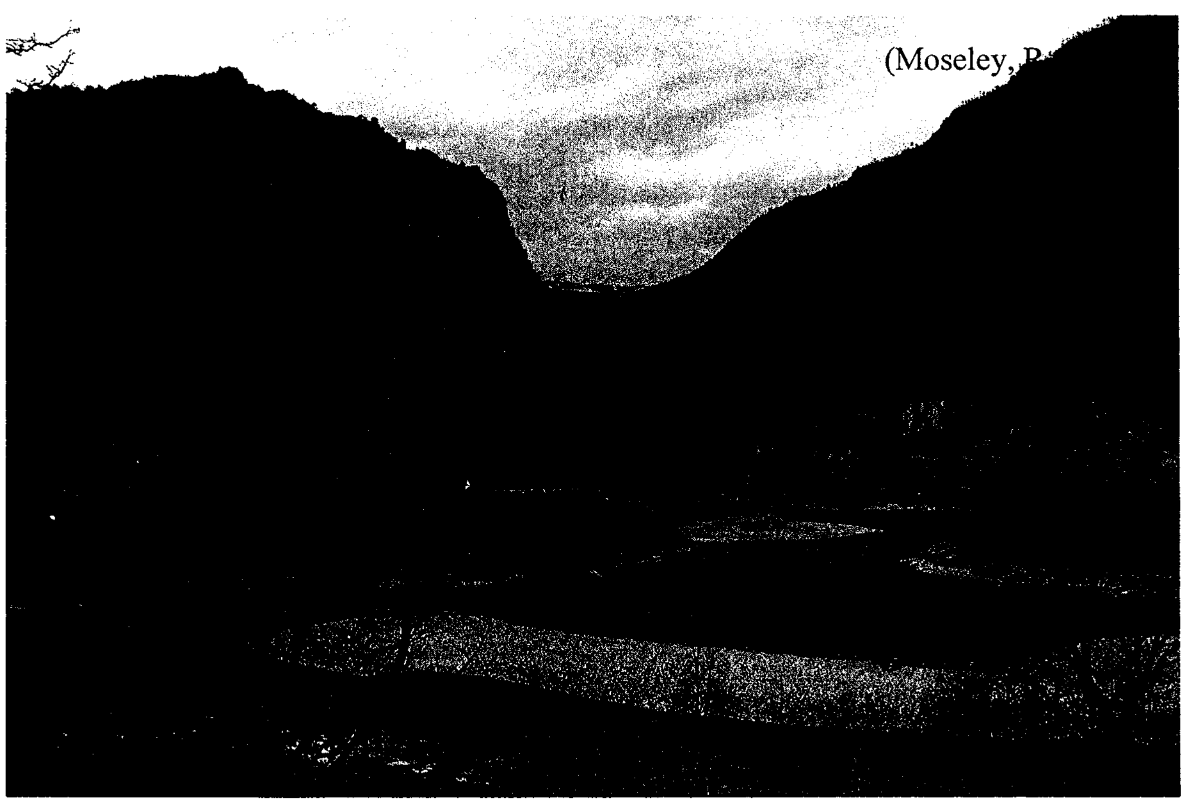


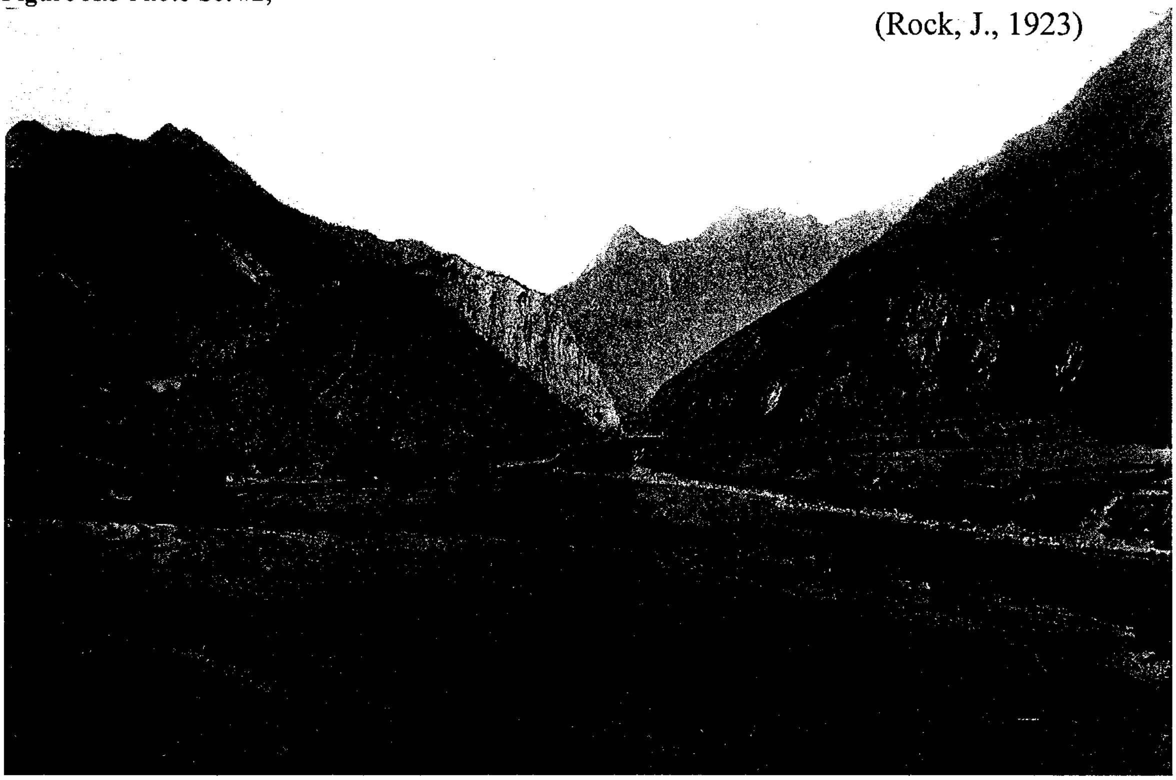
Figure A.2 Photo Set #1,





(George, C., 2008)

Figure A.3 Photo Set #2,



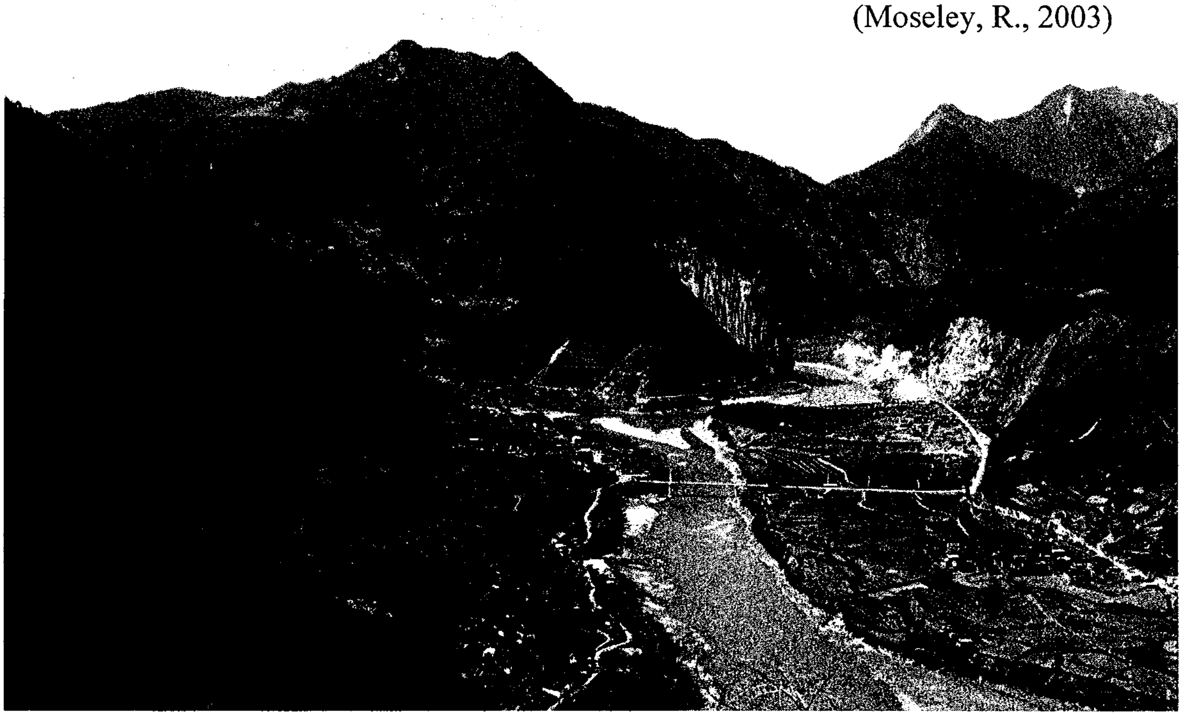
(Rock, J., 1923)

(Moseley, R., 200

Figure A.4 Photo Set #3

(Rock, J., 1923)

(Moseley, R., 2003)



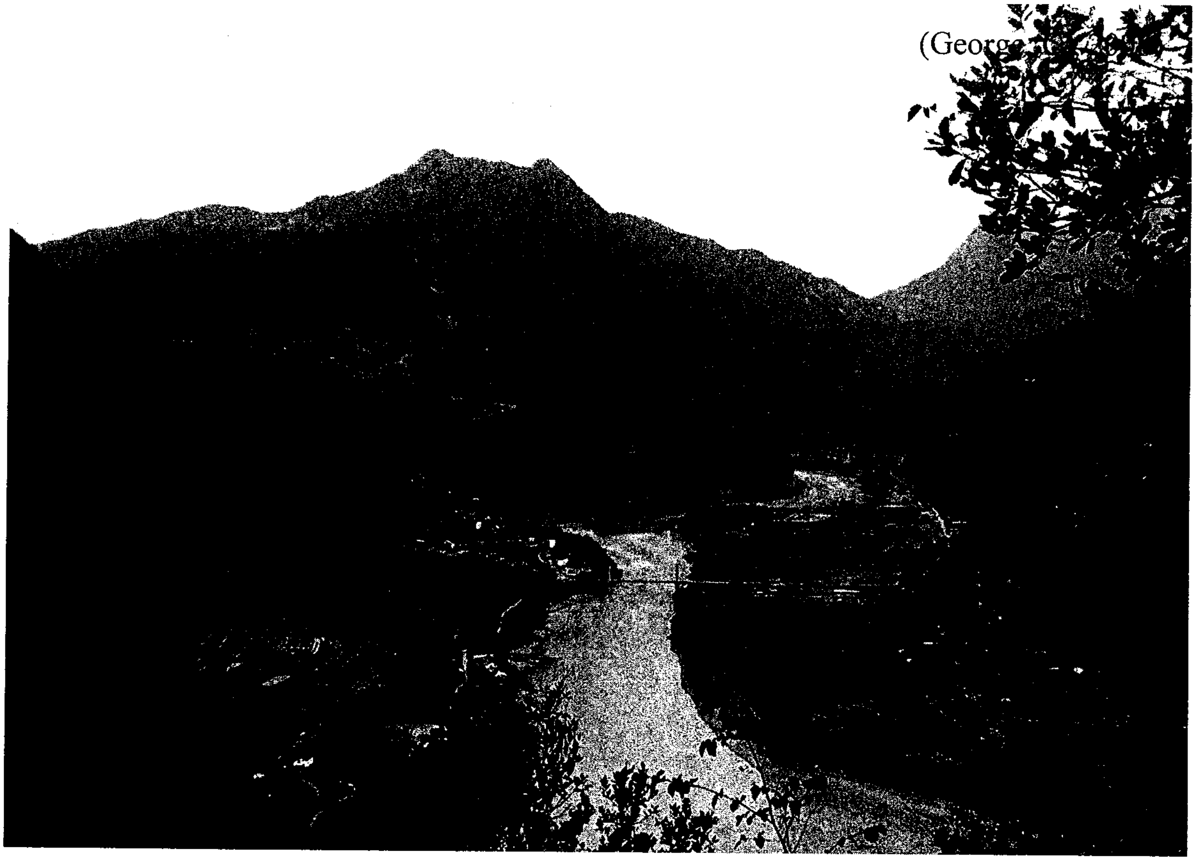
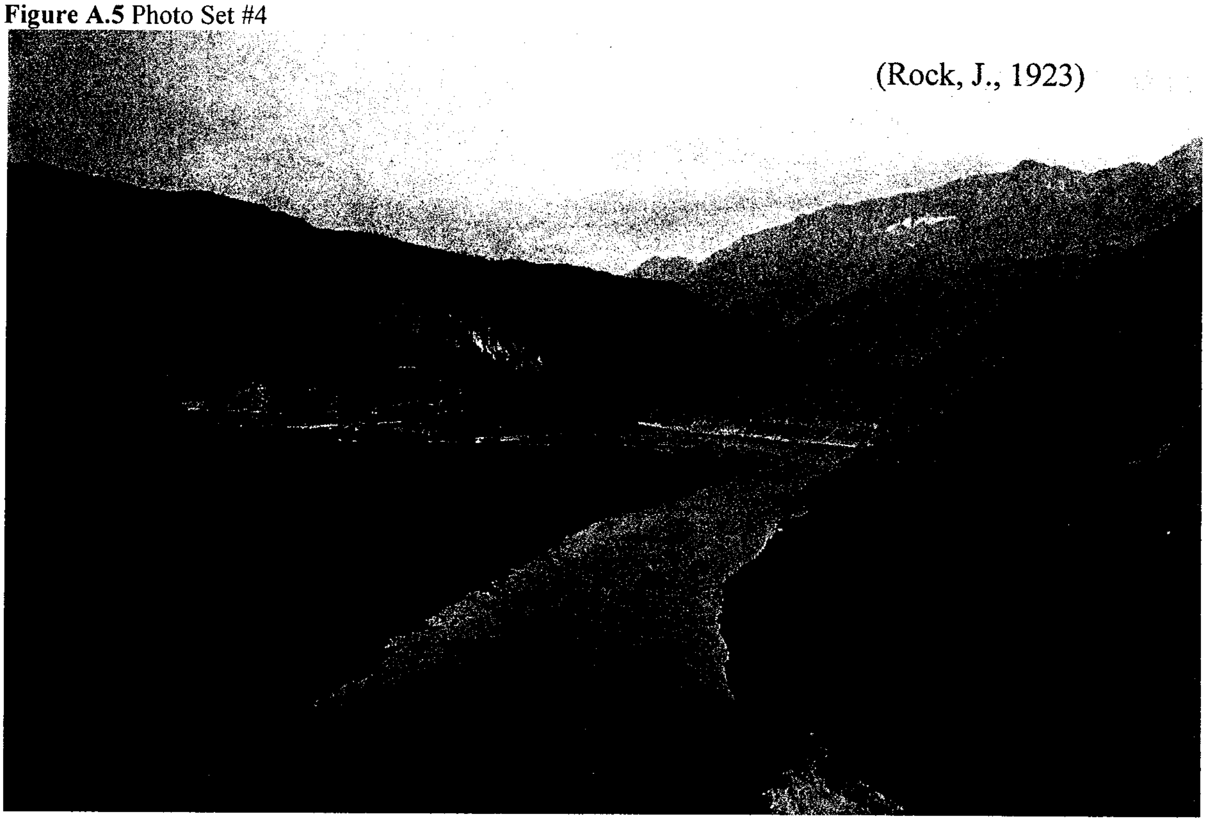

(George

Figure A.5 Photo Set #4



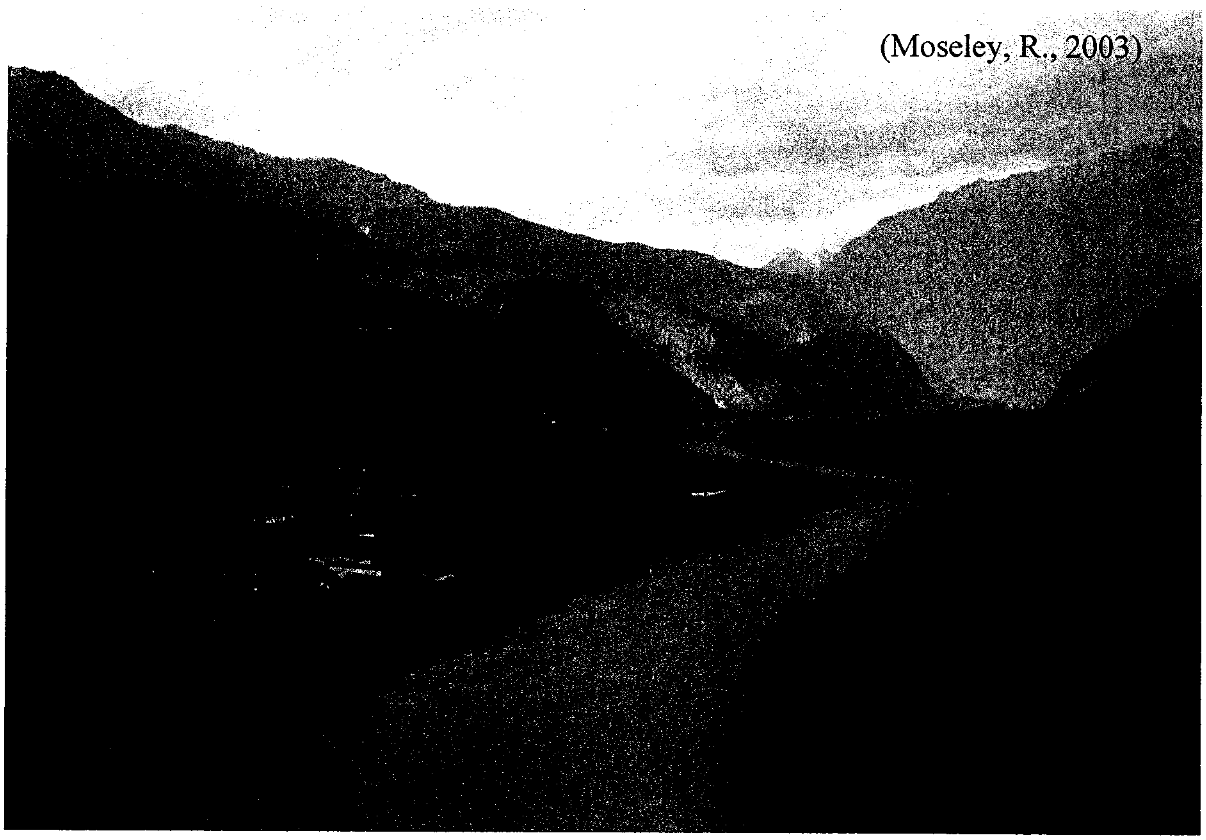


Figure A.6 Photo Set #5

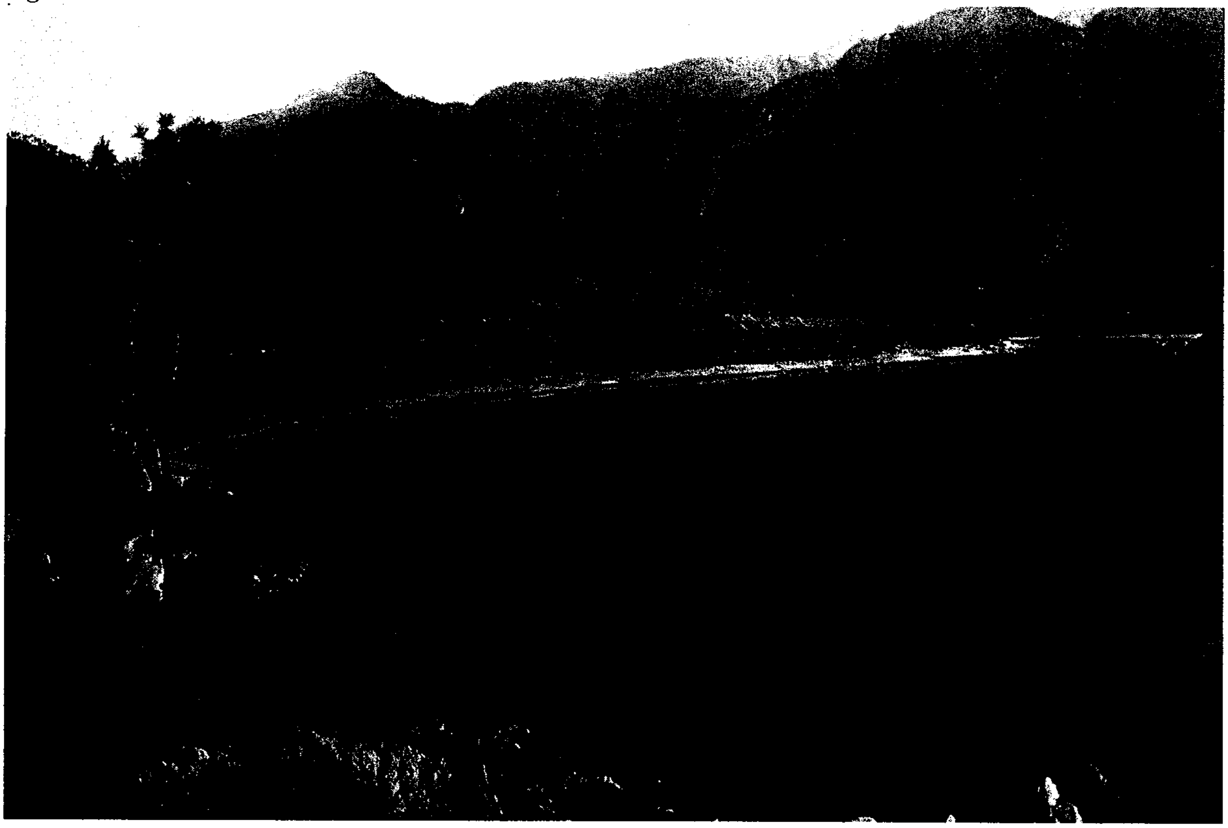


Figure A.7 Photo Set #6

(Rock, J., 1923)

(Moseley, R., 2003)

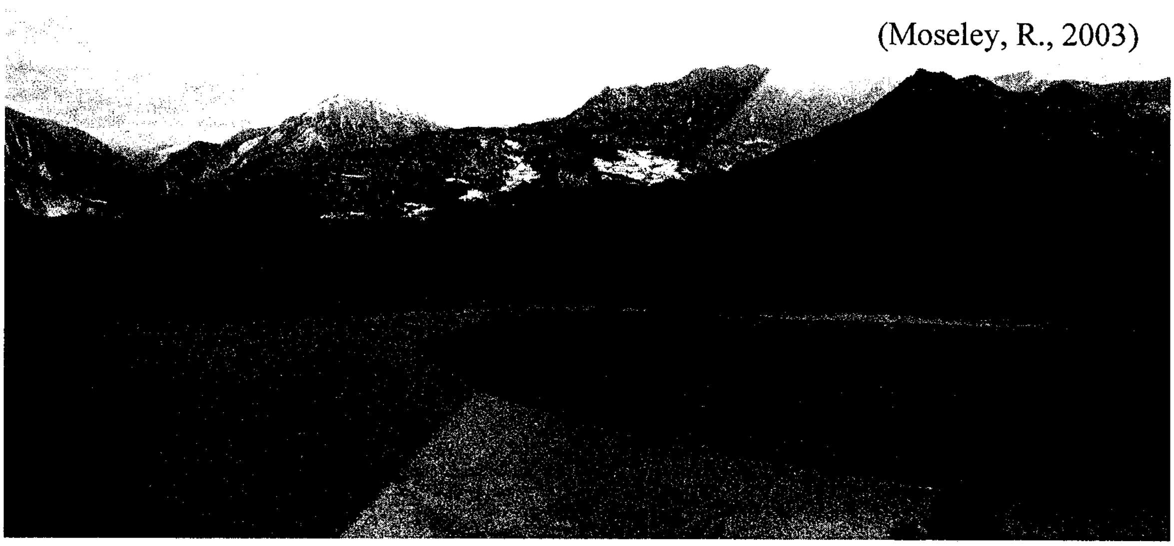
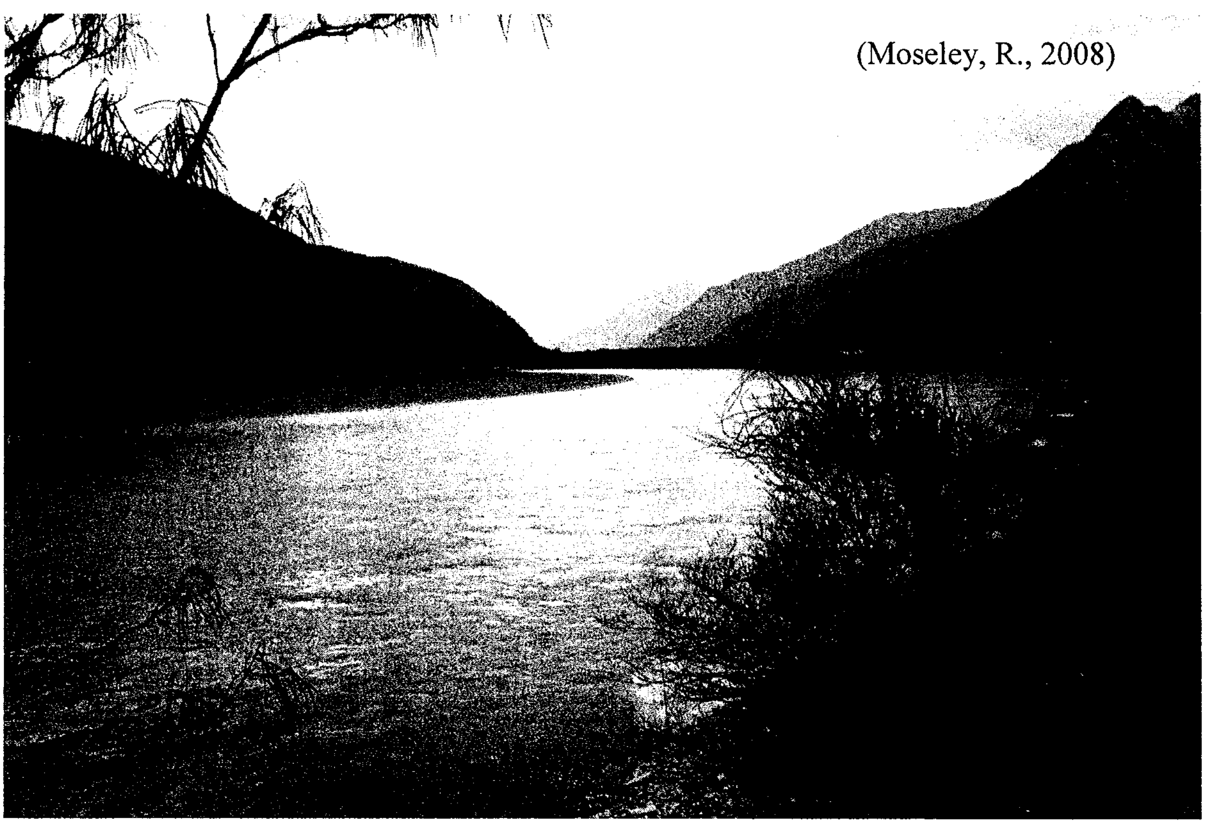


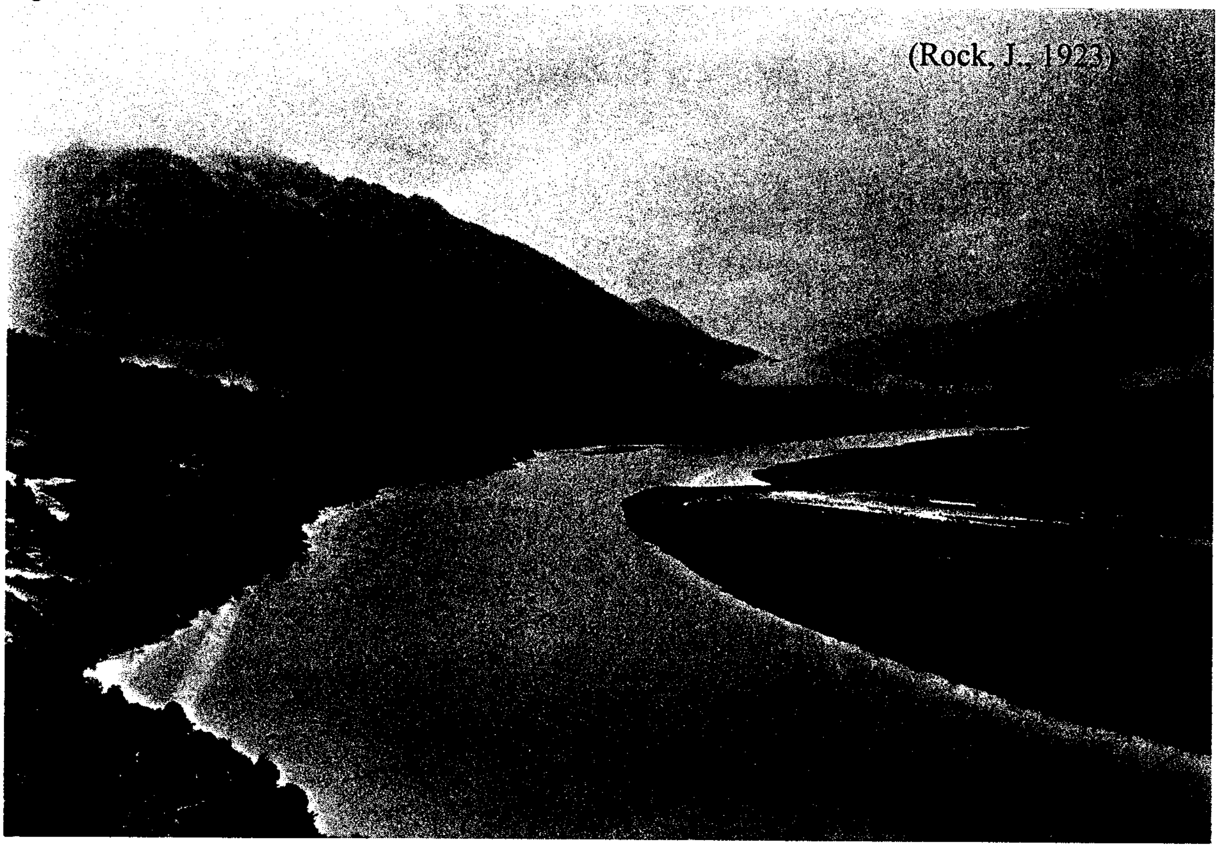
Figure A.8 Photo Set #7

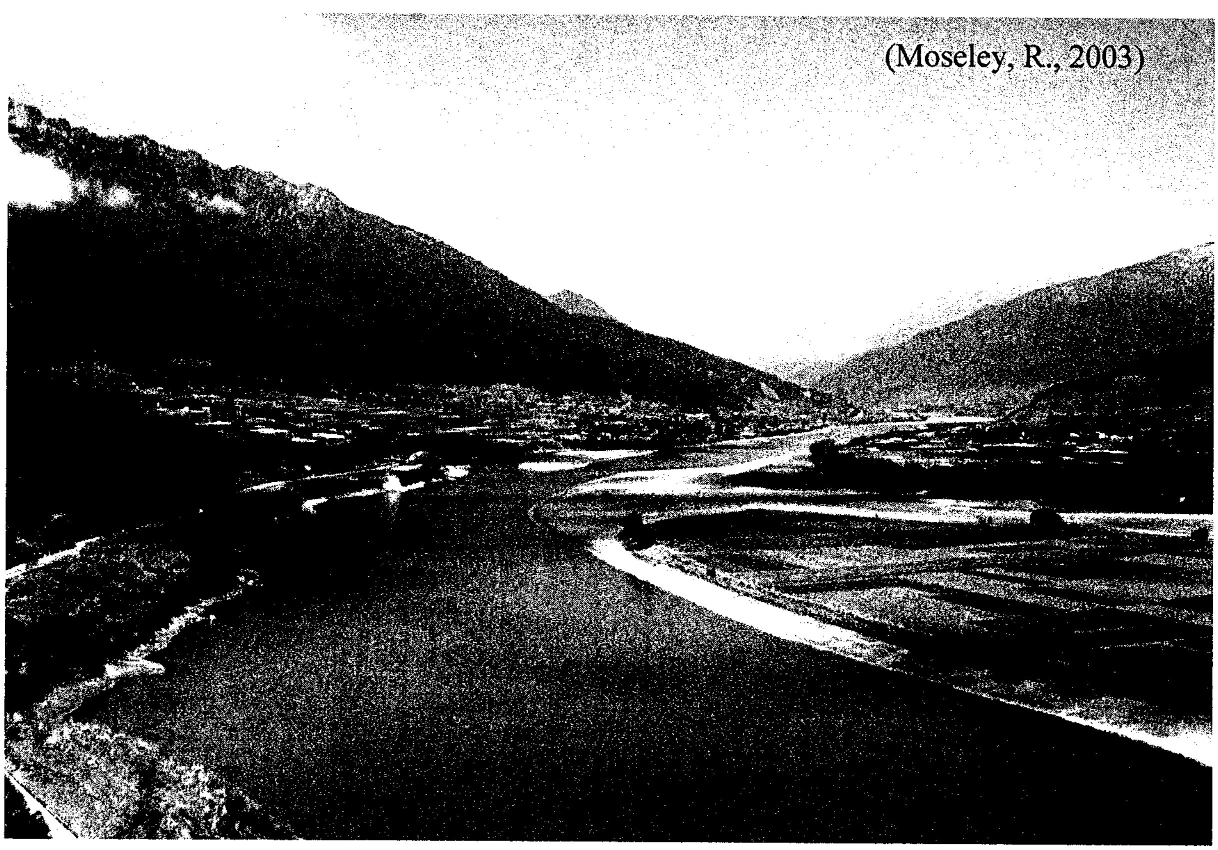
(Rock, J., 1923)

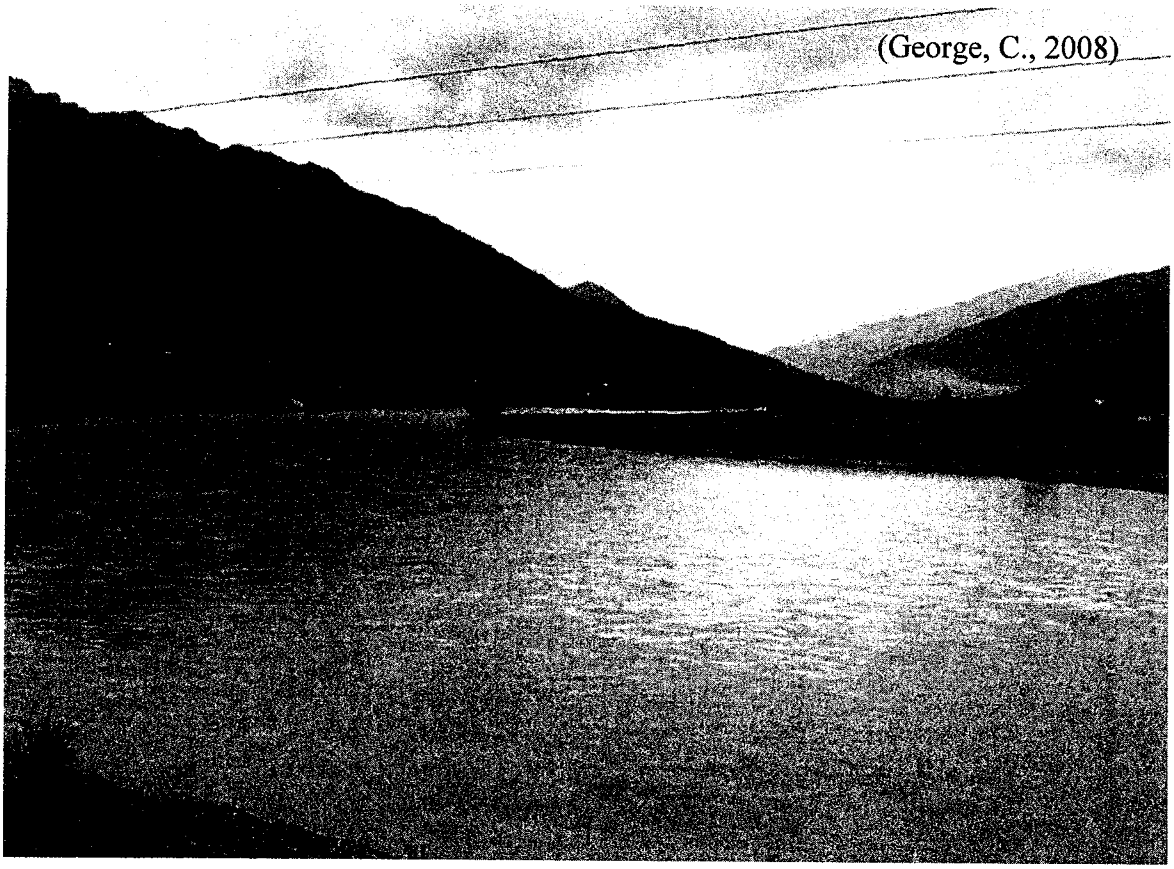


(Moseley, R., 2008)

Figure A.9 Photo Set #8

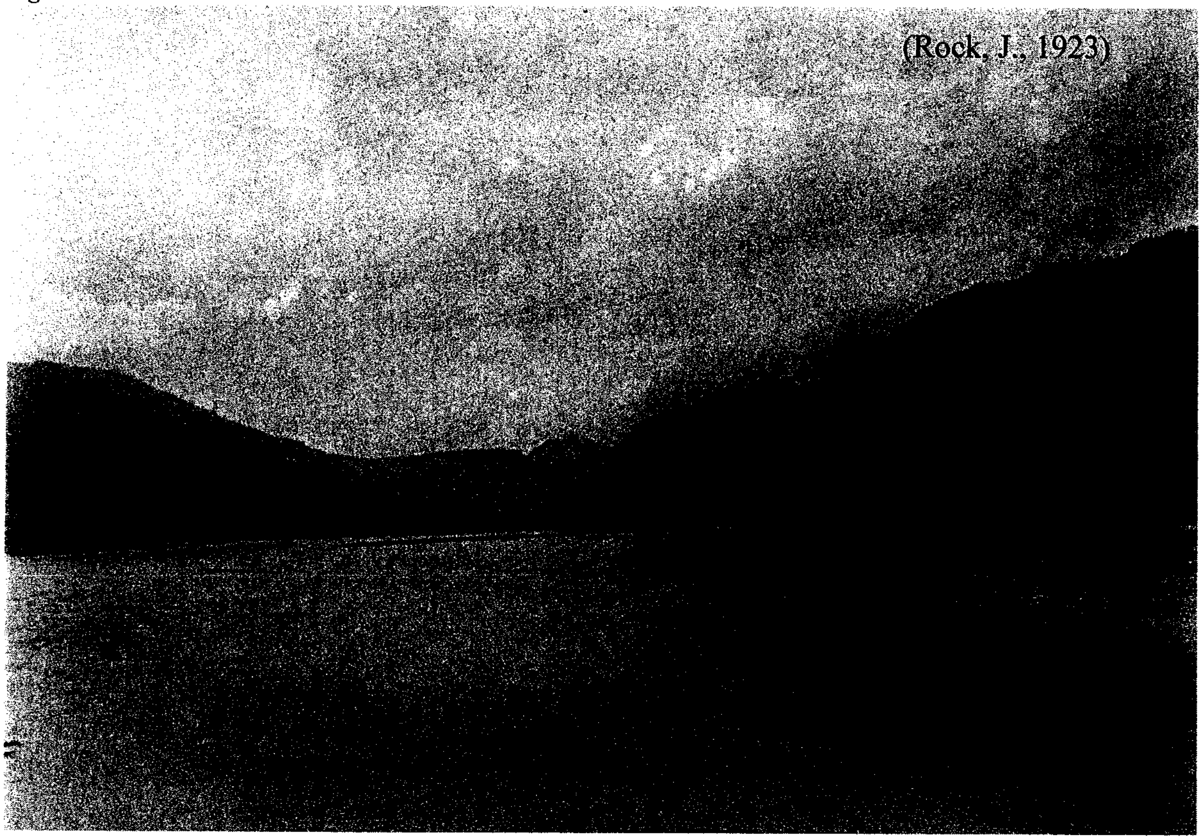






(George, C., 2008)

Figure A.10 Photo Set #9



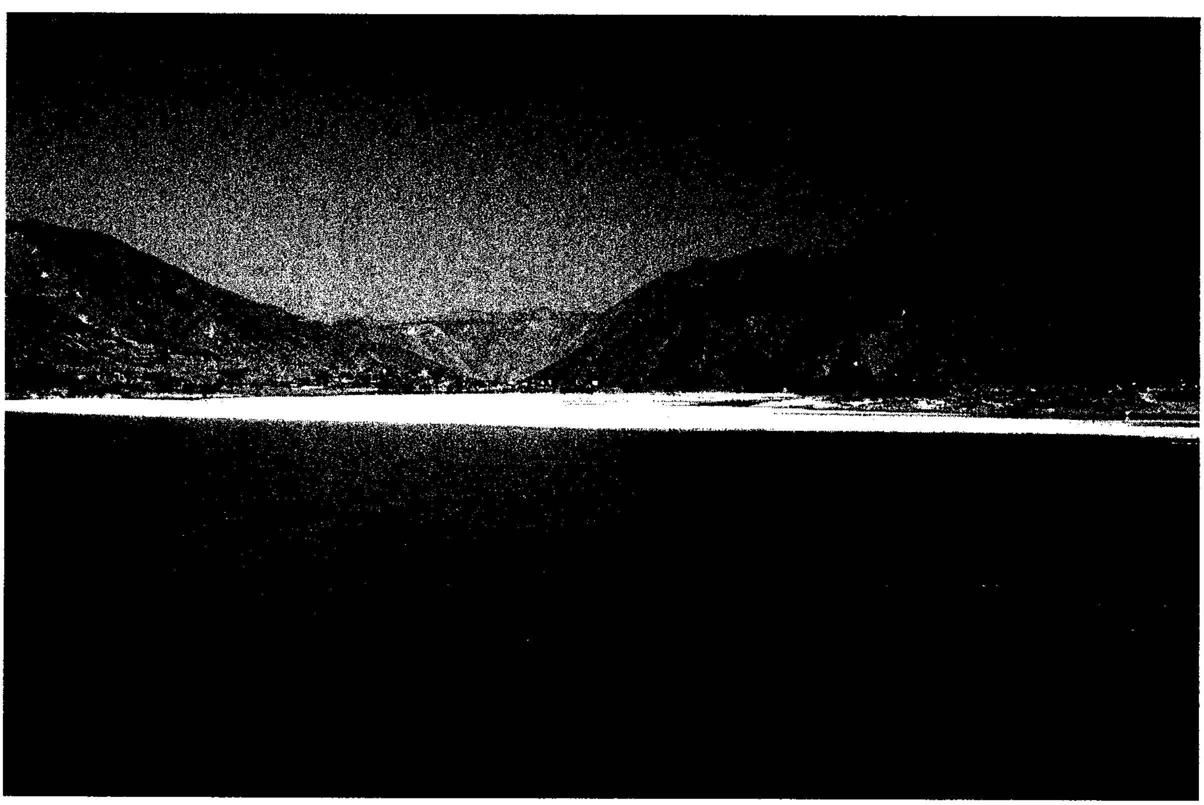
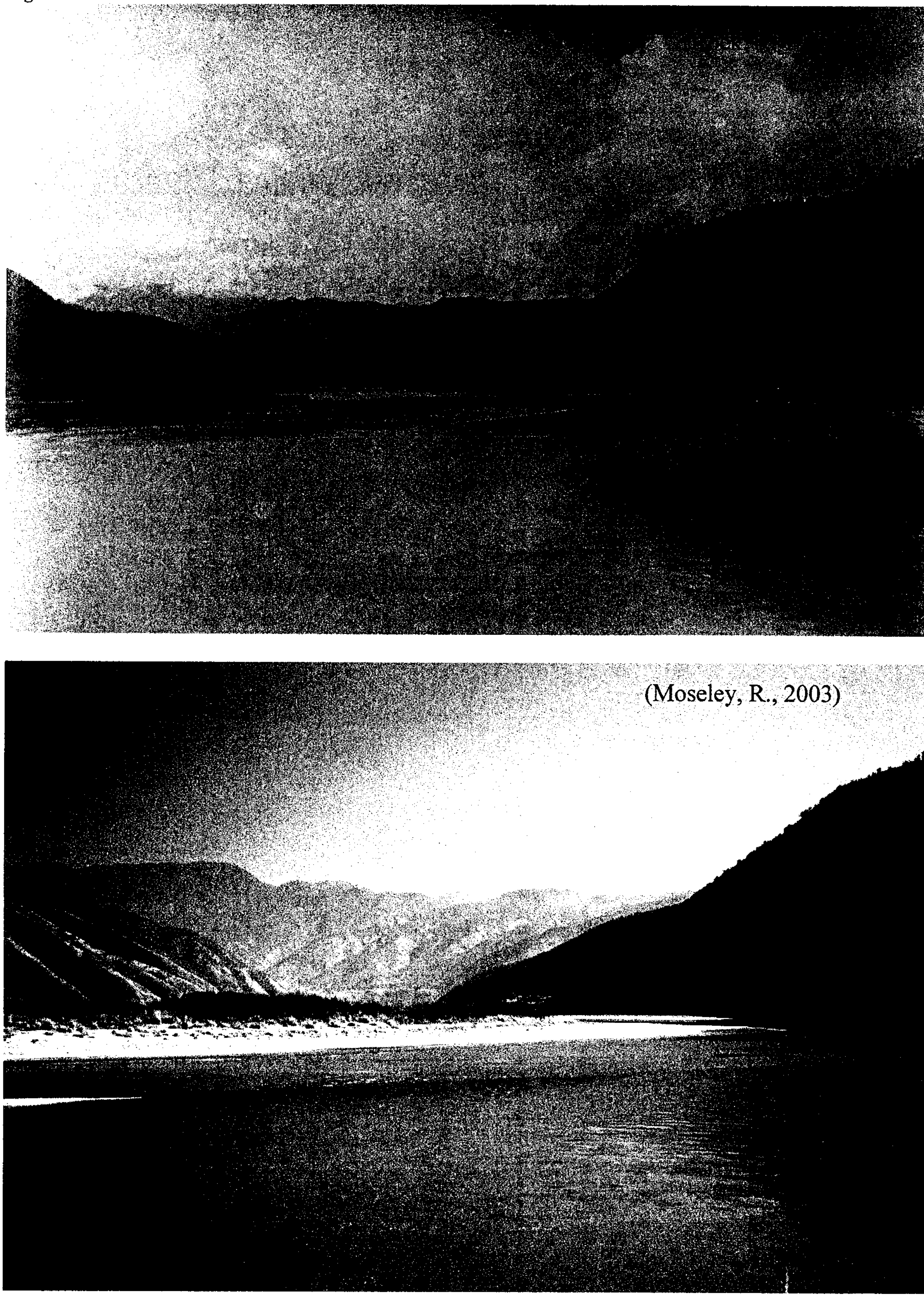


Figure A.11 Photo Set #10



(Moseley, R., 2003)

Figure A.13 Photo Set #11

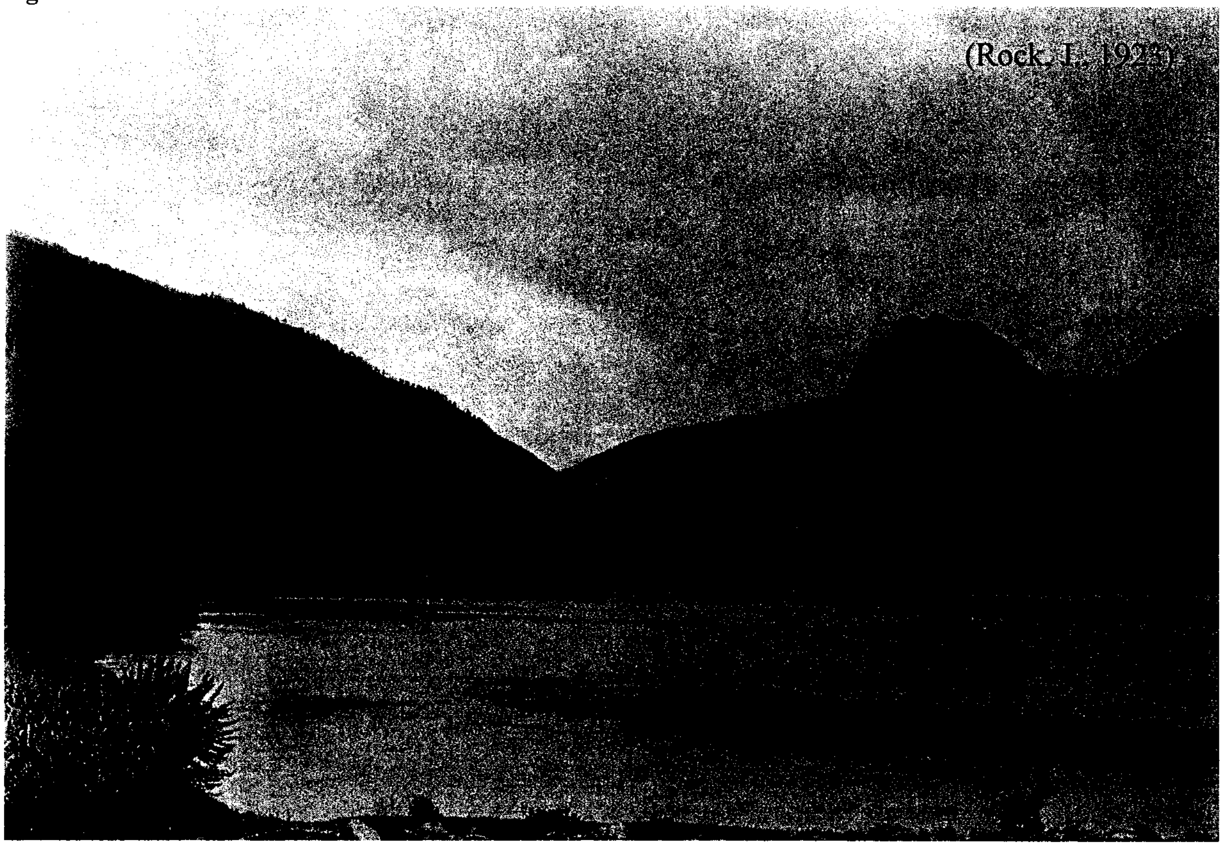


Figure A.13 Photo Set #12

(Rock, J., 1923)

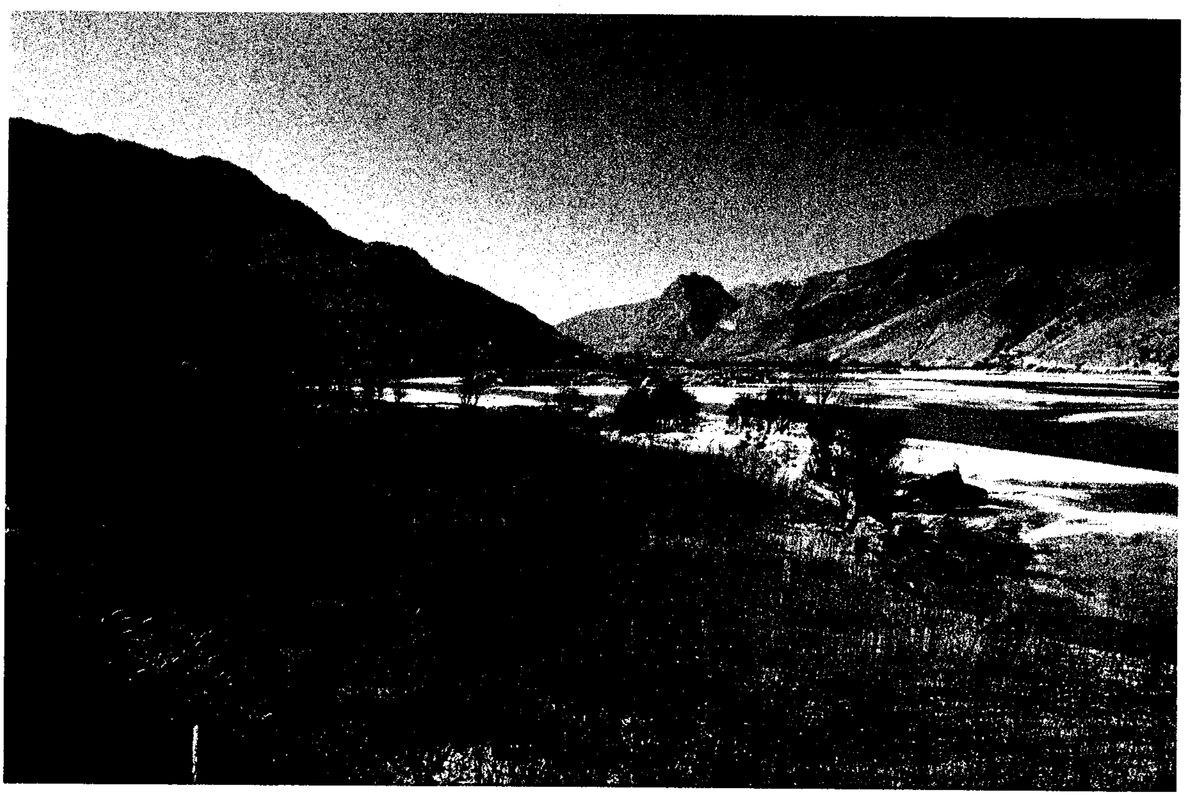
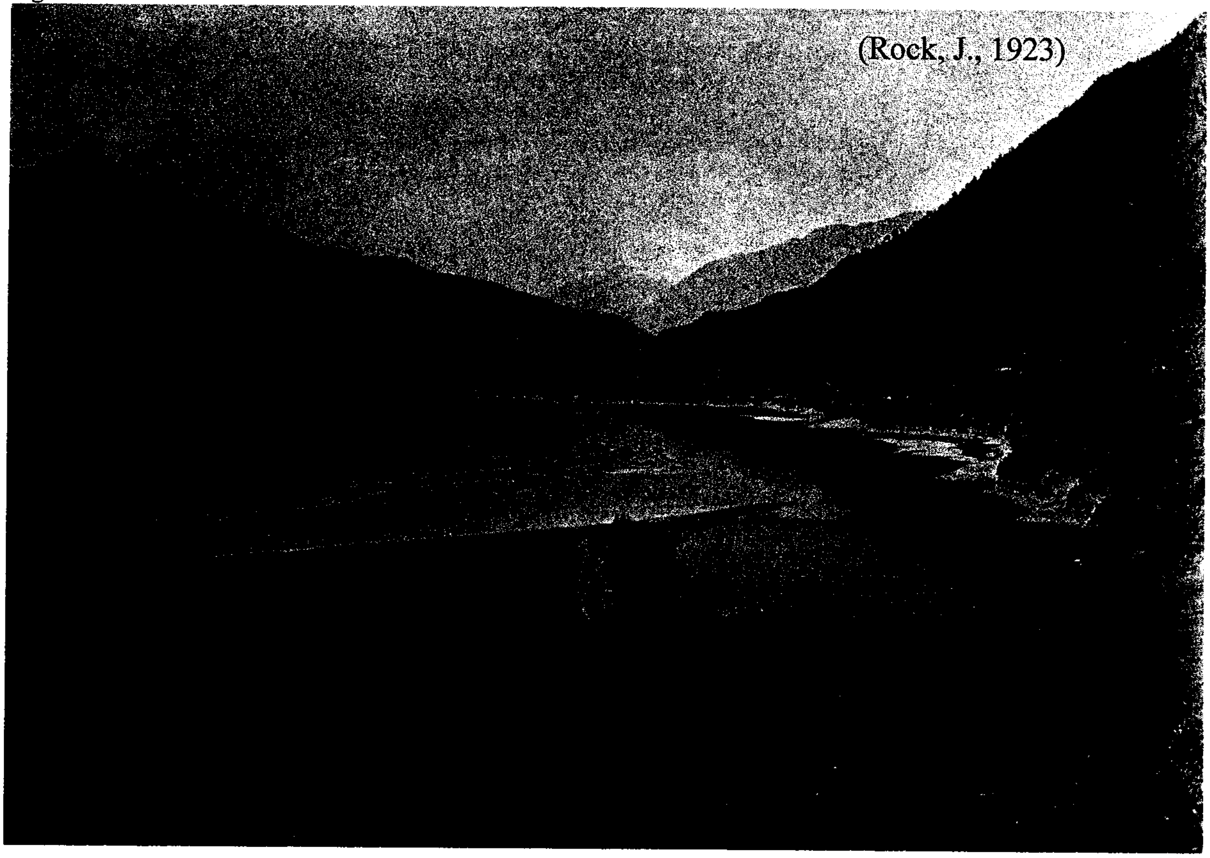


Figure A.14 Photo Set #13



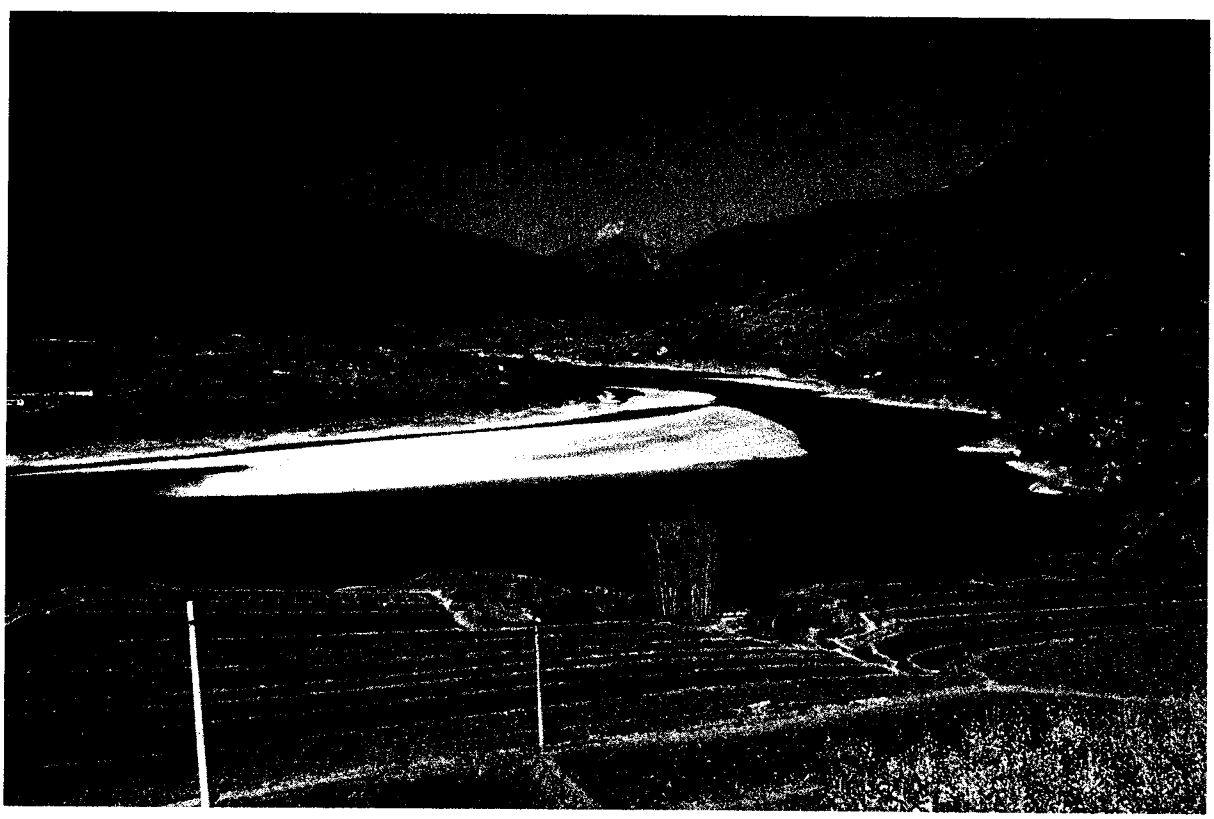
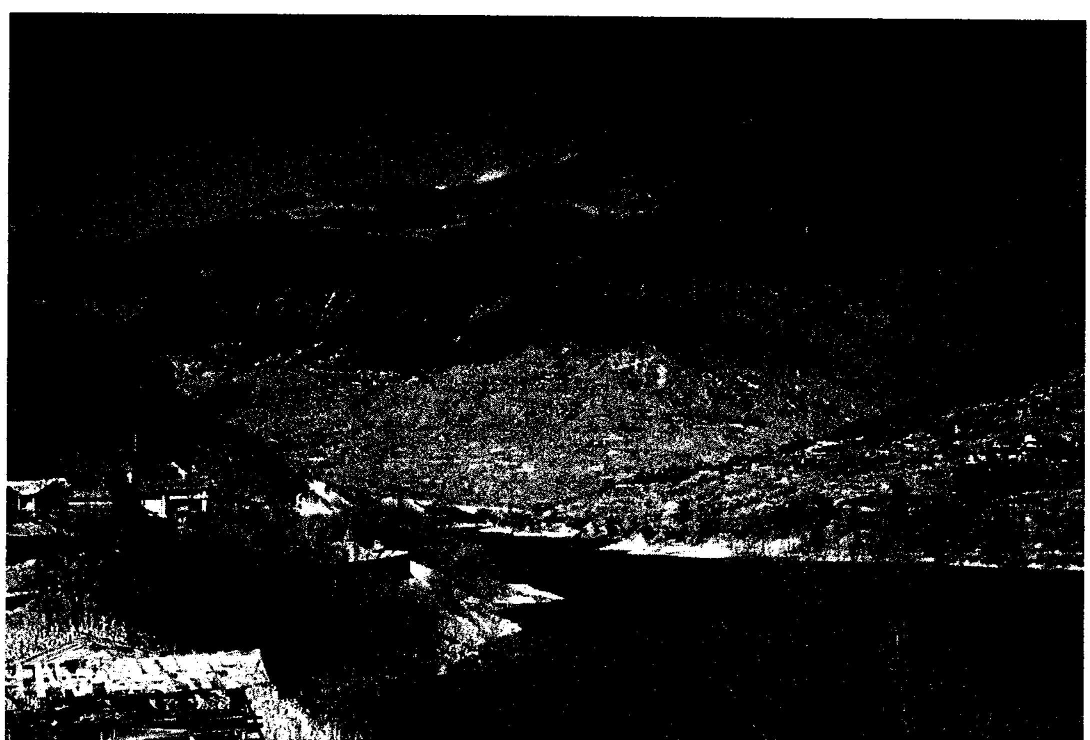


Figure A.15 Photo Set #14



(George, C., 2008)

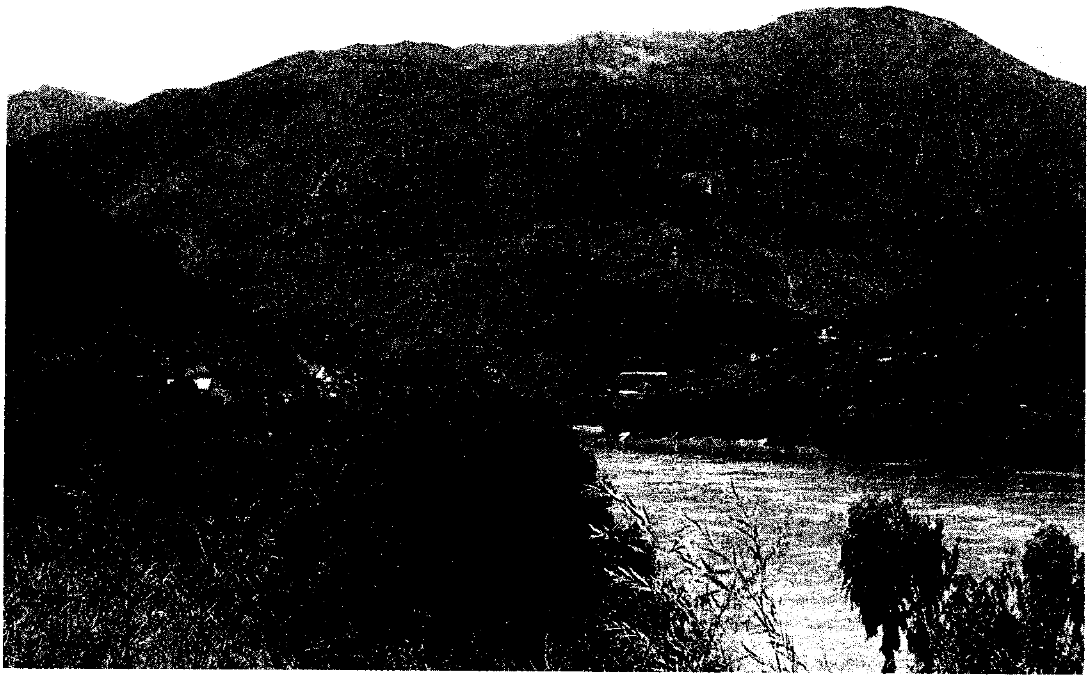


Figure A.16 Photo Set #15

(Rock, J., 1923)

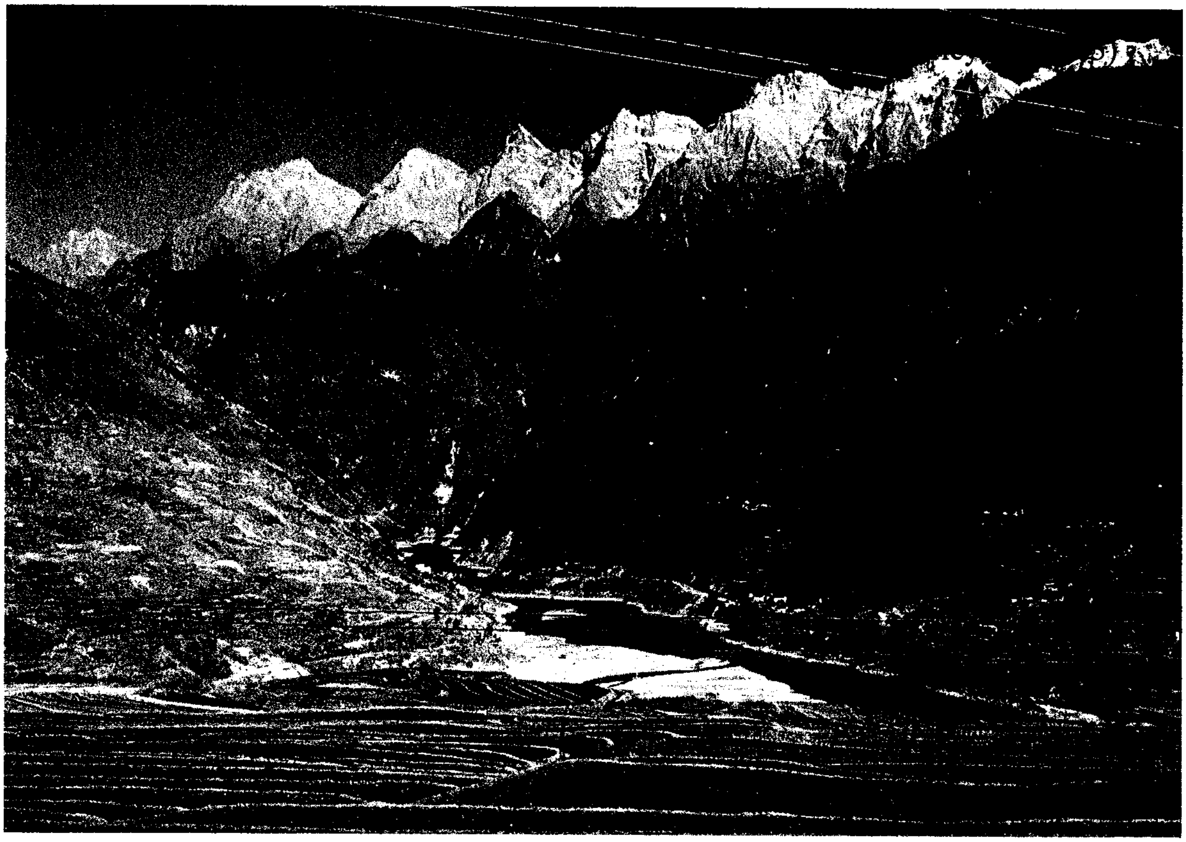
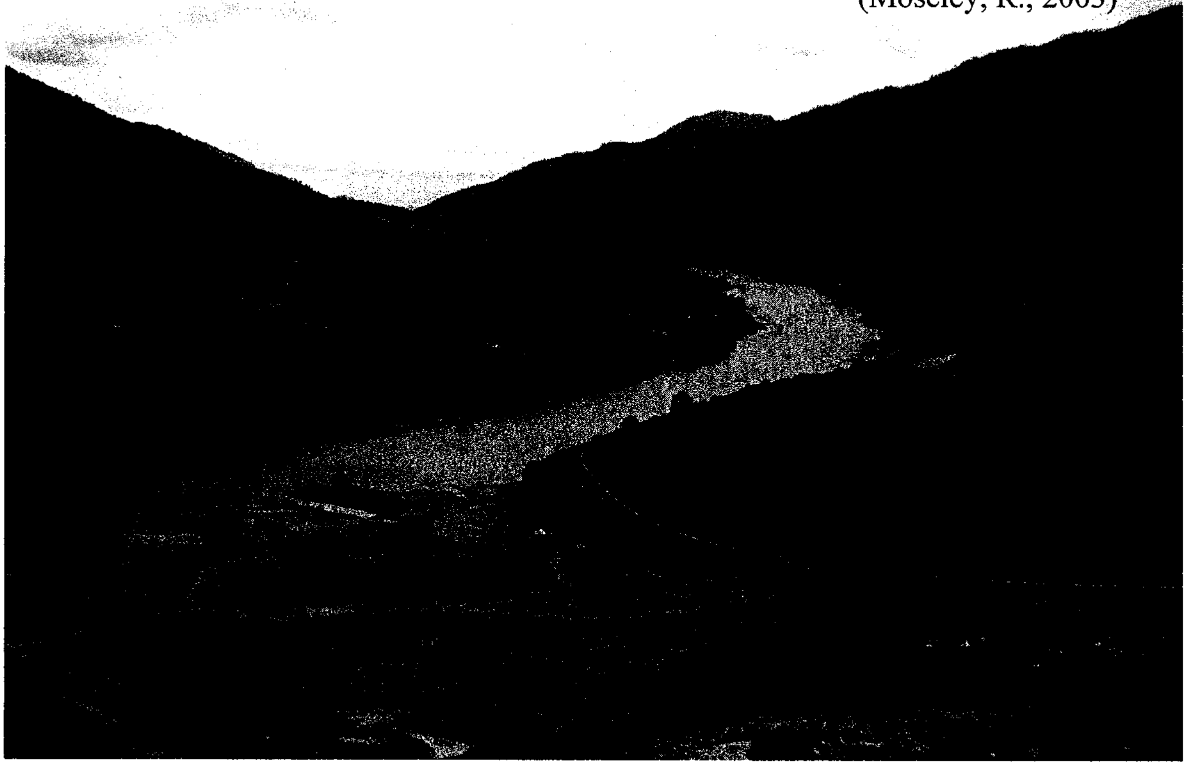


Figure A.17 Photo Set #16

(Rock, J., 1923)

(Moseley, R., 2003)



(George, C., 2008)

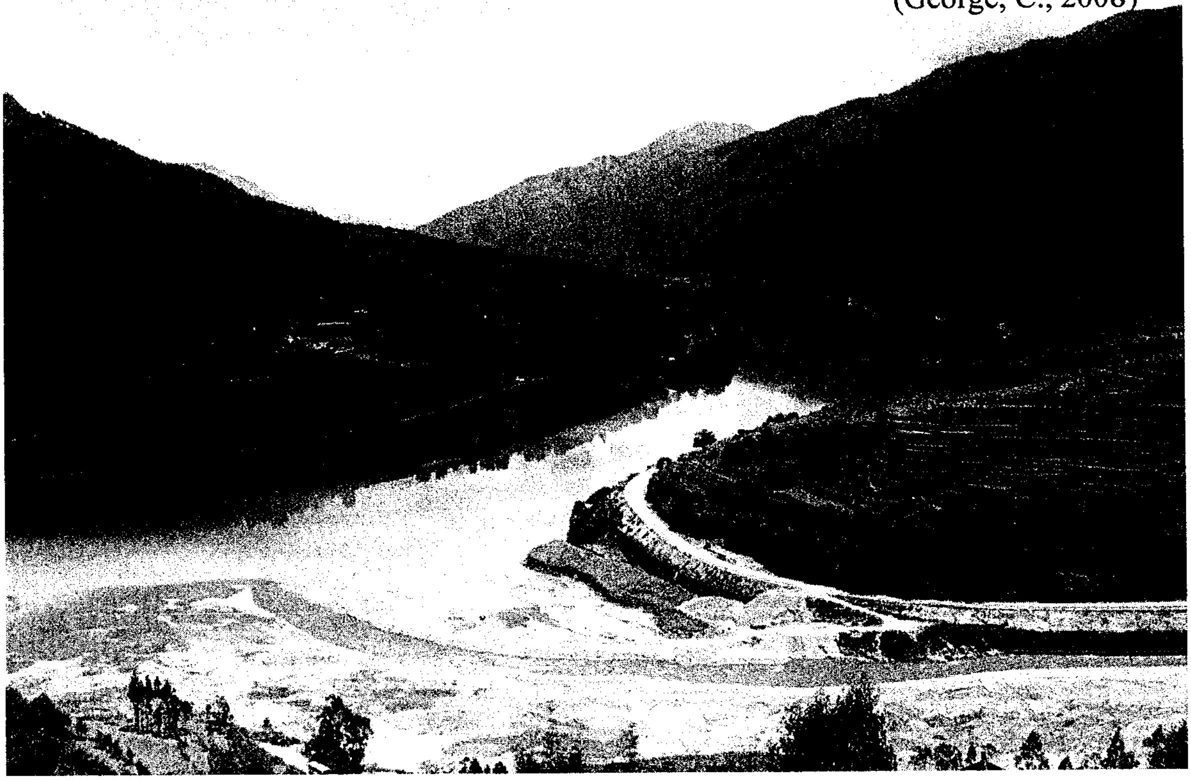
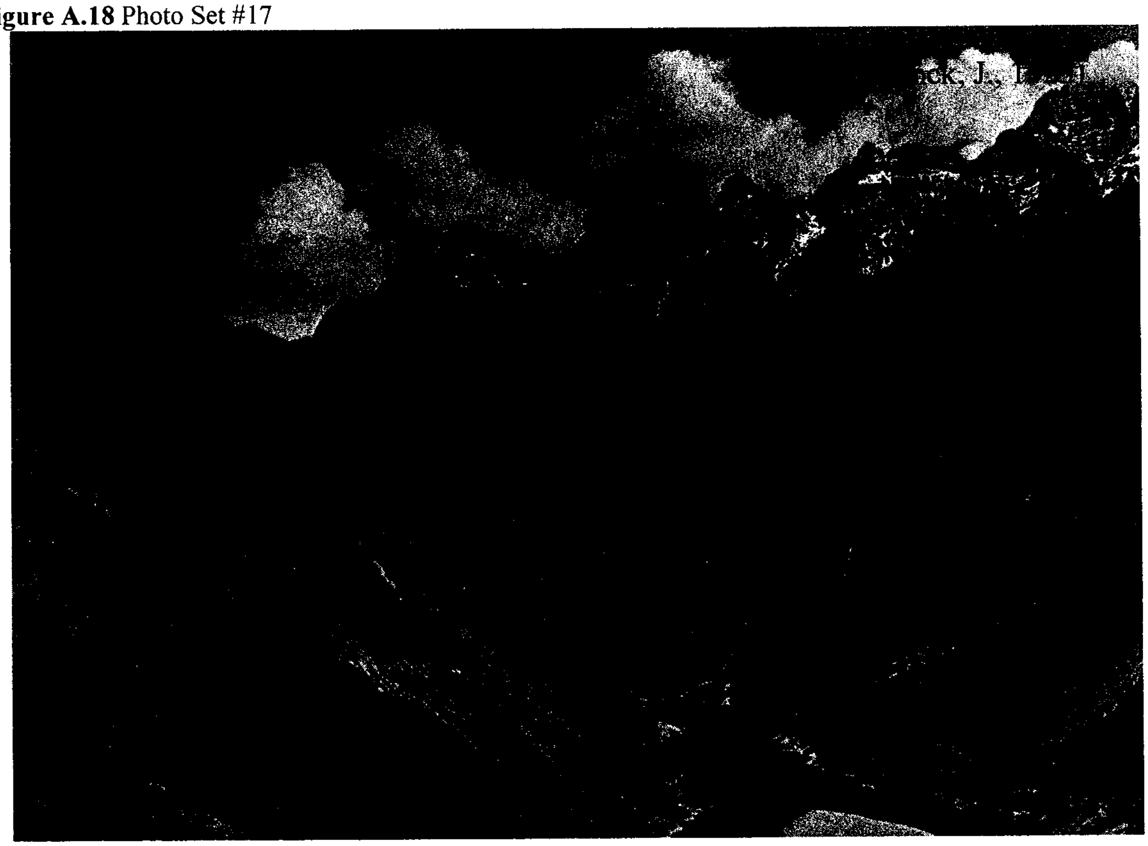
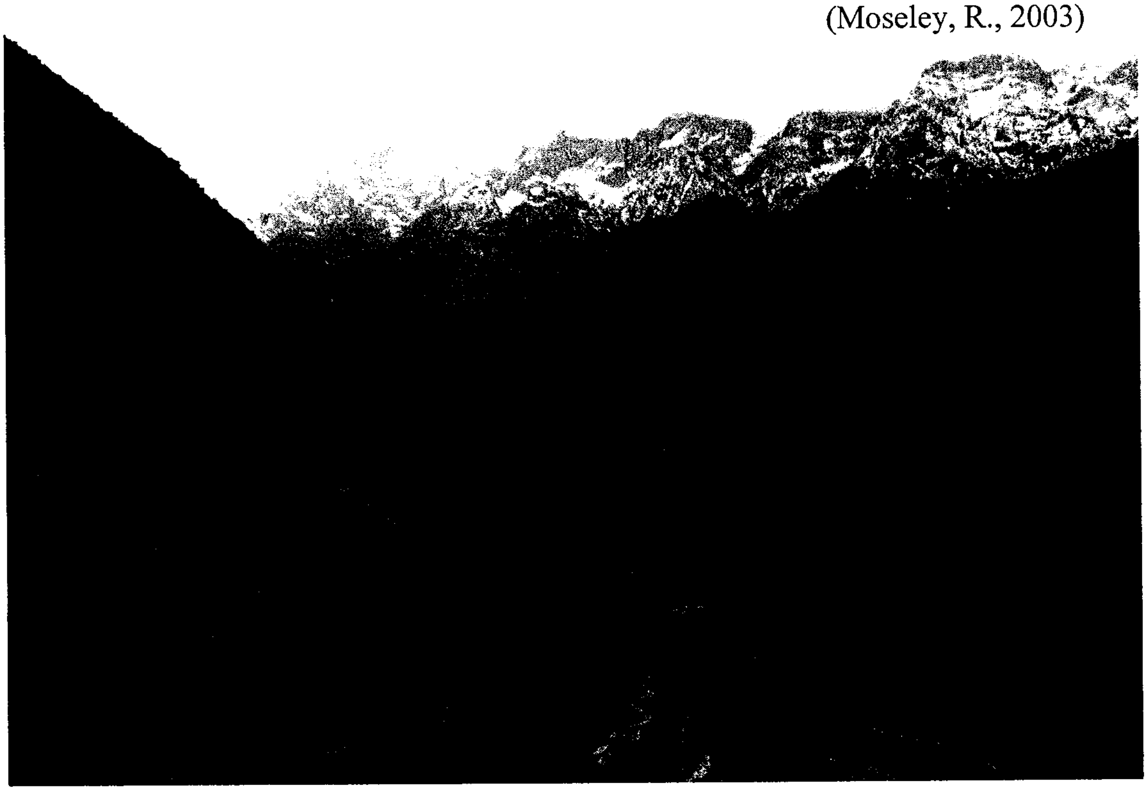


Figure A.18 Photo Set #17



(Moseley, R., 2003)



(George, C., 2008)

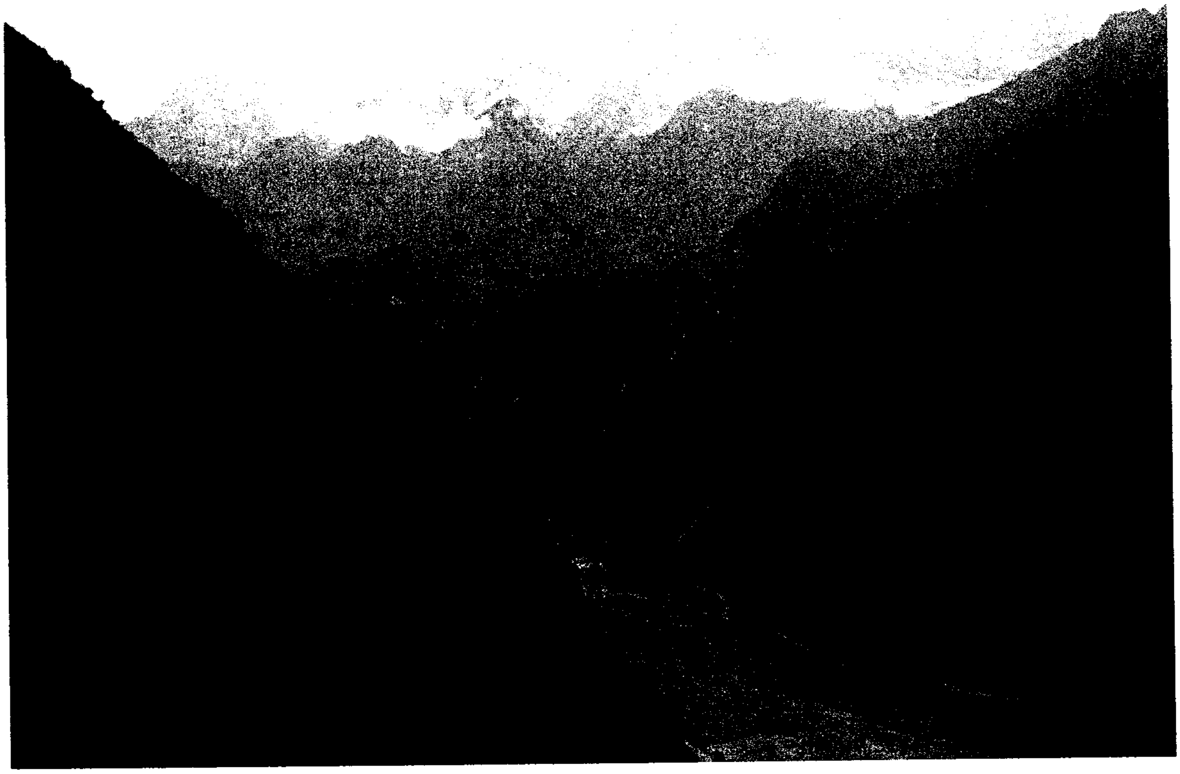
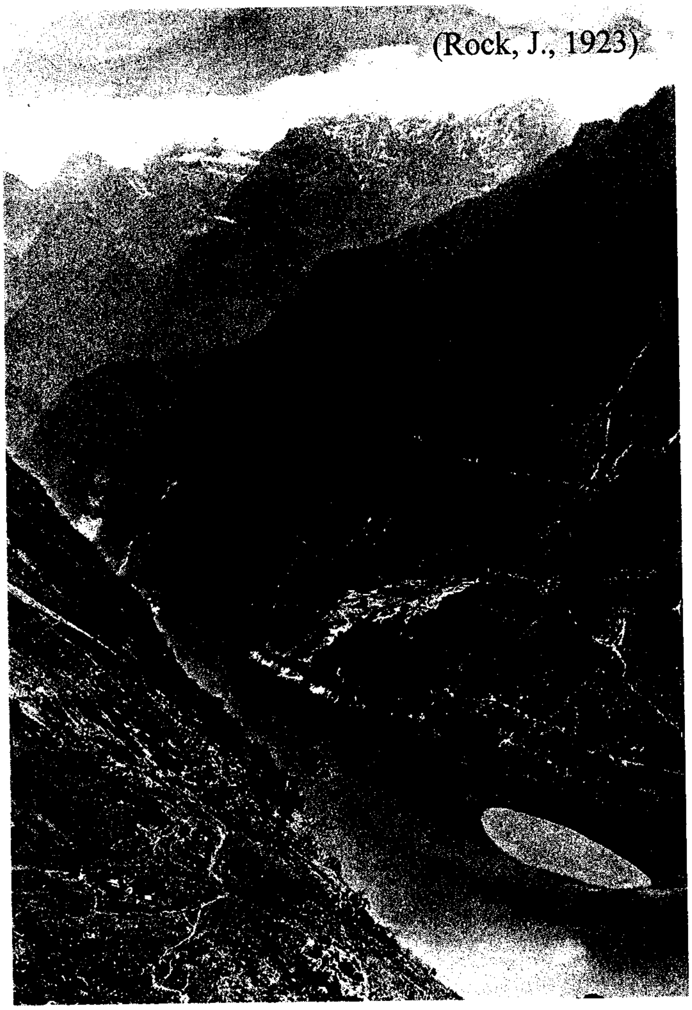


Figure A.19 Photo Set #18



(Moseley, R., 2003)

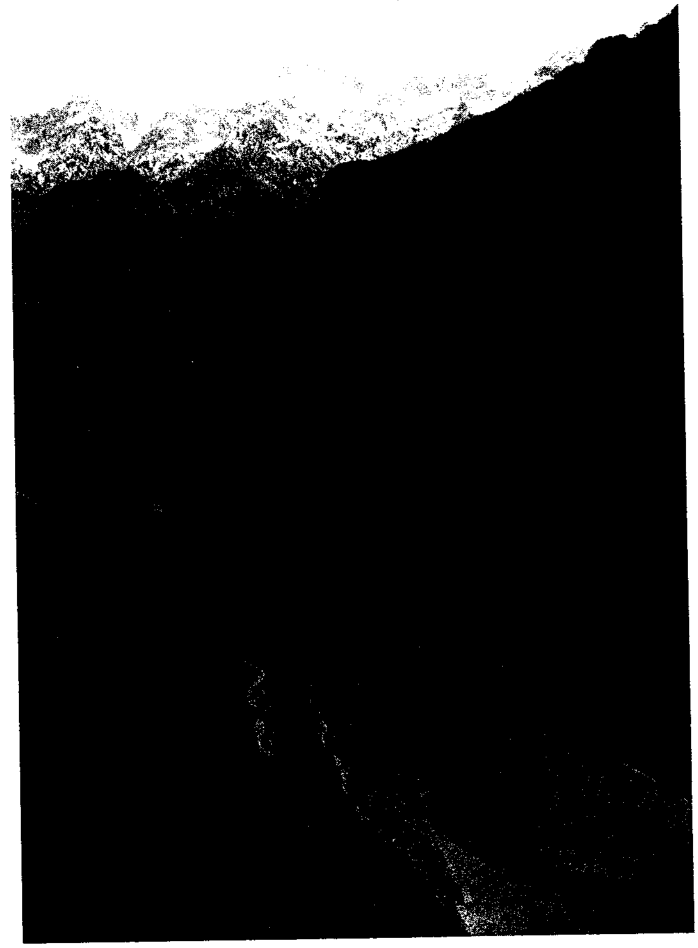
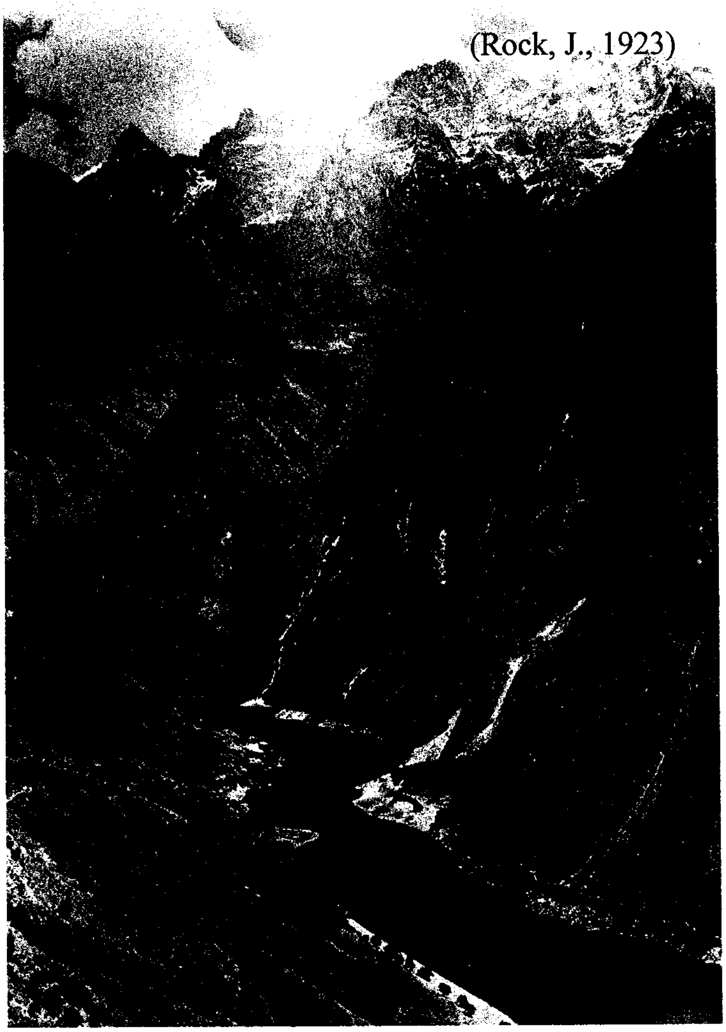
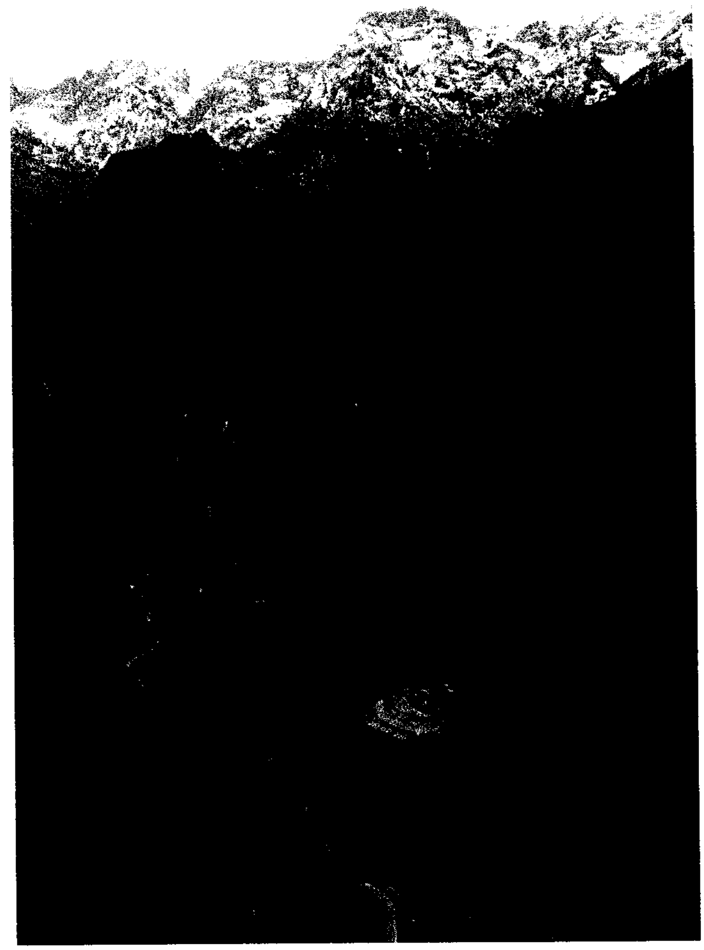


Figure A.20 Photo Set #19



(Rock, J., 1923)



(Moseley, R., 2003)

(George, C., 2008)

Figure A.21 Photo Set #20

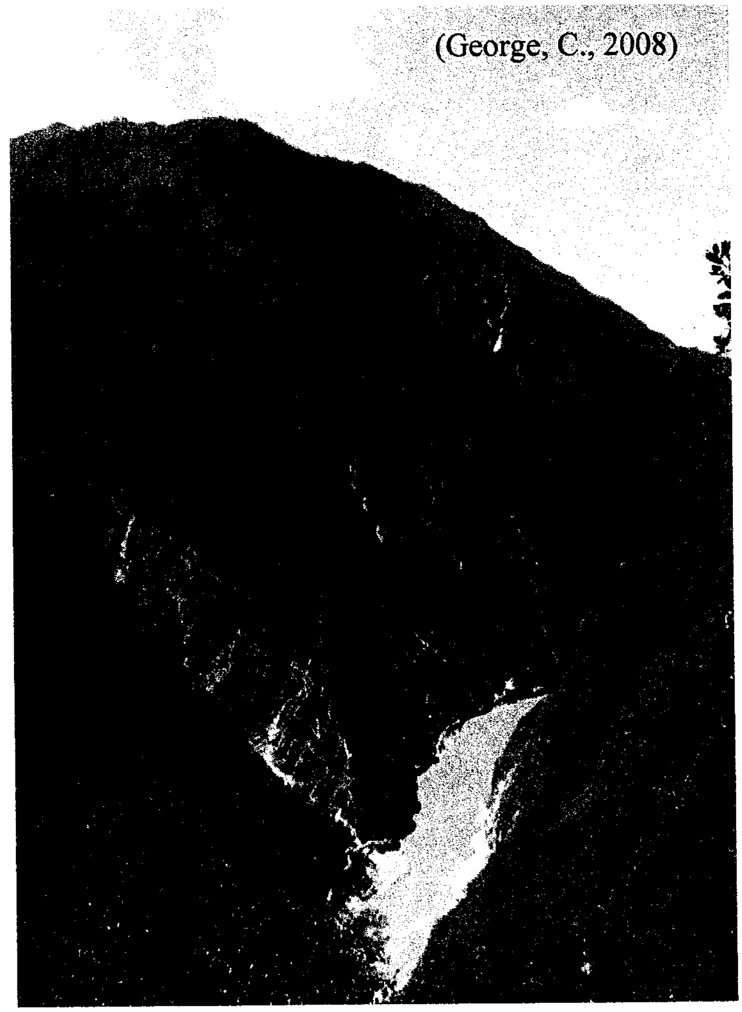
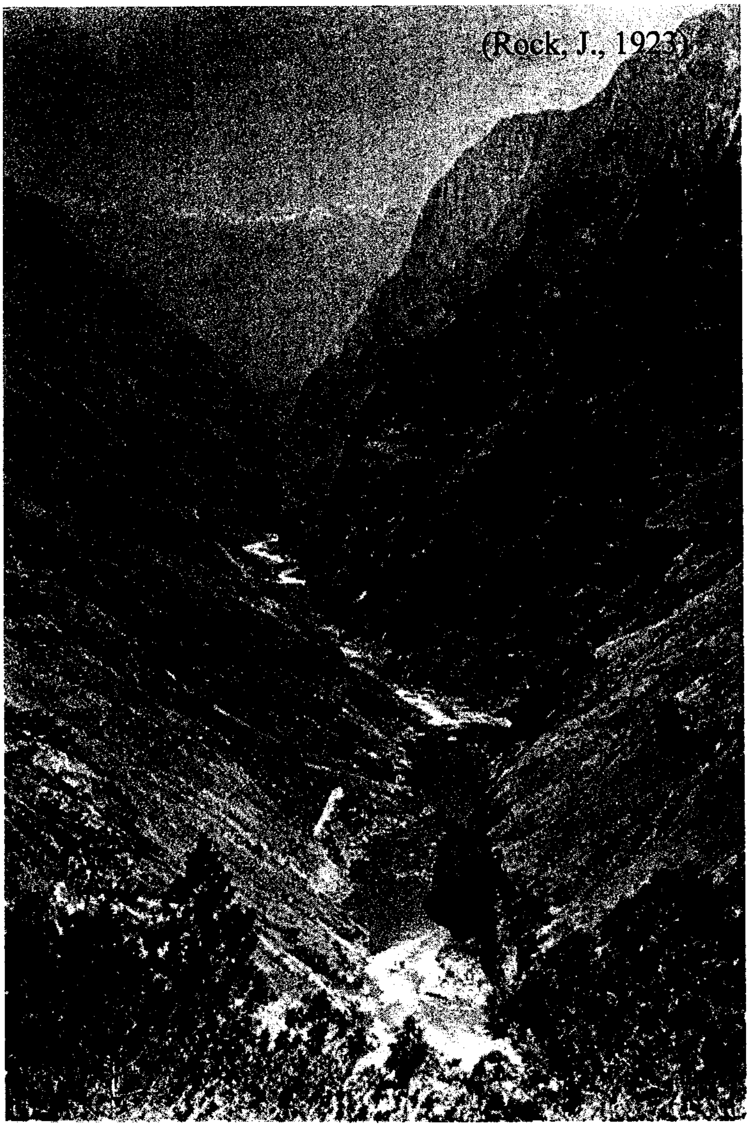


Figure A.22 Photo Set #21



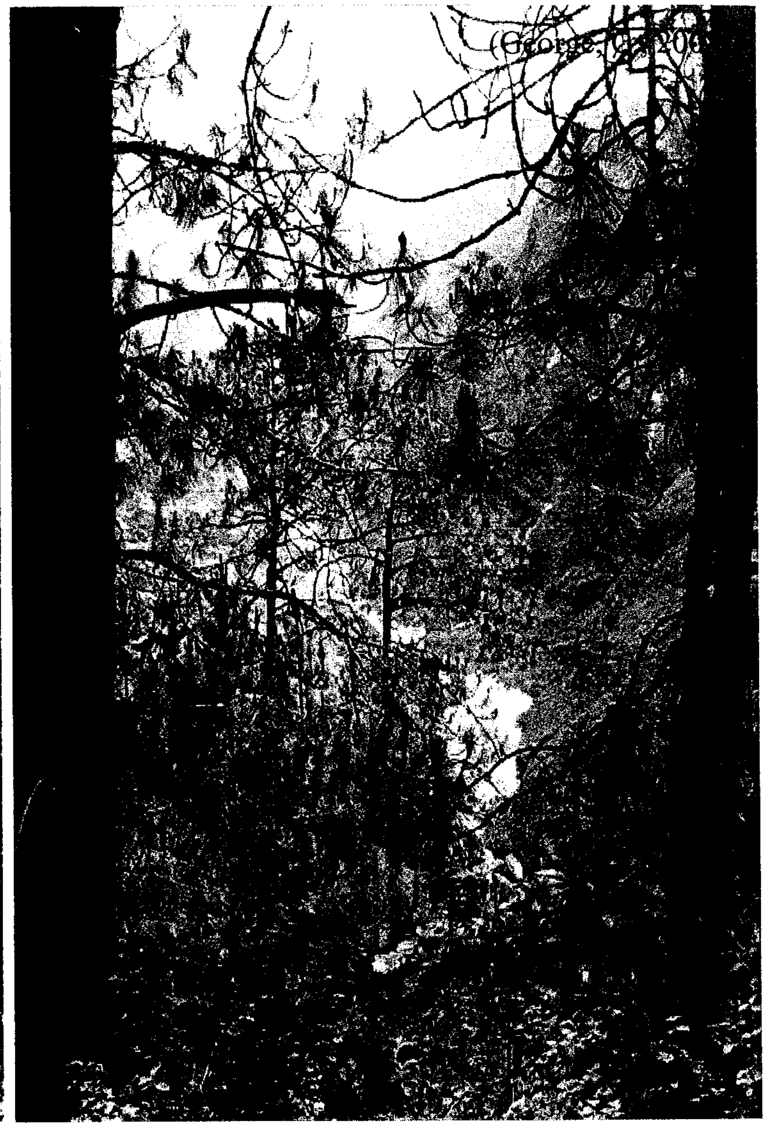
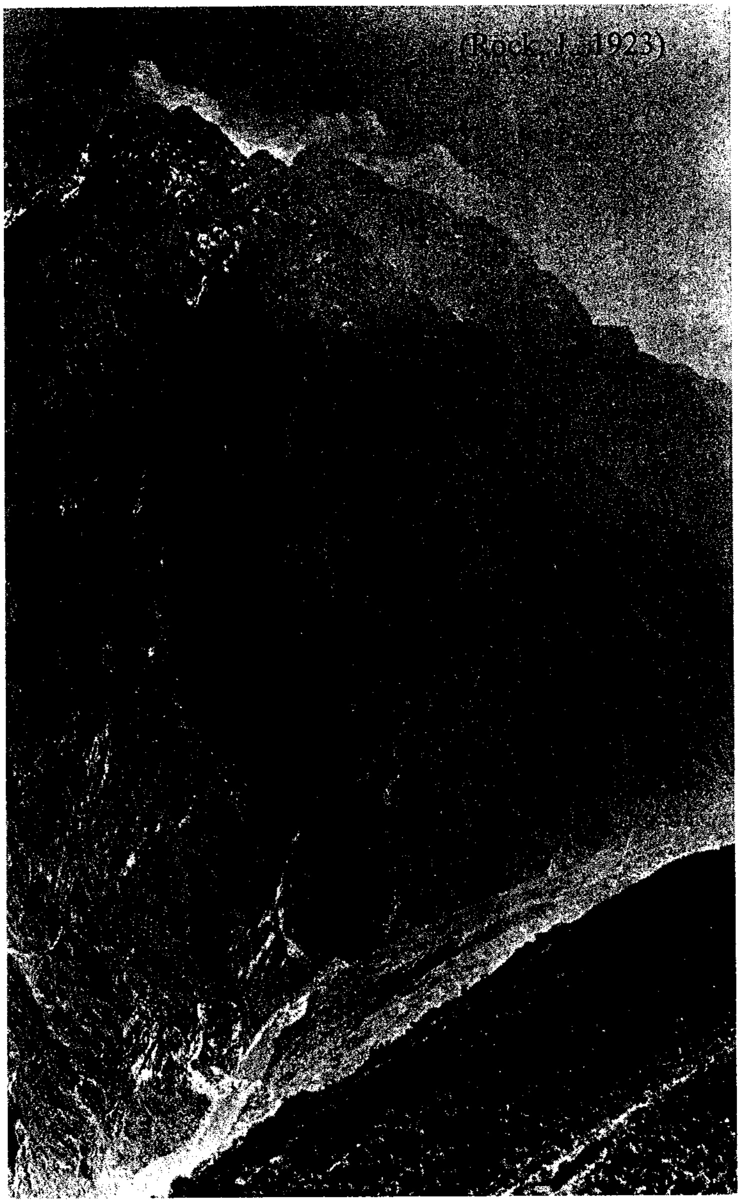


Figure A.23 Photo Set #22



APPENDIX B:
CATALOGING PHOTO INFORMATION
FIELDWORK NOTES

This appendix offers the reader detailed information about each of the photo points for the photographs retaken by me in 2008. As well as the political area that each photograph was taken in, I recorded the precise location of each photo point using GPS and noted the direction that I was facing to replicate the shot. As well as noting the location, I took additional field notes to document the prominent landscape characteristics. This included information about the vegetation communities, land cover, land use, infrastructure, and disturbance present in the landscape shown in each photograph. Finally, I recorded the conditions during the time that I replicated each shot, including the time and date, the air quality, and any difficulty that I encountered when retaking the photograph.

Photo Set #1

Table B.1 Cataloging in-field photo information for Photo Set #1

Photo Information	Explanation	Photo Set #1
Location	Description of the location and directions to photo point	Yangtze River at the meeting of Deqin County, Wexi/Lisu County and Shangri-la County
GPS	Latitude-Longitude, Altitude	27°34"45.1" N-99°31.25.0" E, 1944 m
Orientation	Direction faced to retake photo (compass bearing)	2°
County	Political location of photo point	Deqin, Wexi/Lisu and Shangri-la County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, mixed forest, some woodlands indicating timber extraction and grazing, montane conifer forest suspected at higher altitudes
Land Cover	Dominant vegetation	*Pinus yunnanensis/P. densata,* various deciduous spp., *Juglans* planted along river
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	Significant cultivation, no recent logging evident, pasture lands at higher altitudes
Infrastructure	Transportation, industrial and power infrastructure	Major roads present on river edges, religious temple on roadside, power lines present, border roadways (significant landscape degradation evident to put in power lines)
Disturbance	Soil erosion, forest clearing, mining	Significant settlement build-up, mass wasting has occurred due to road construction
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 3, 2008; 9:57 AM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Very cloudy, foggy - mountains and higher hills cannot be seen
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	Stream bank vegetation was in the way when attempting to take the photograph from the original photo point, I had to move in front of the trees, closer to the water's edge.

Photo Set #3

Table B.2 Cataloging in-field photo information for Photo Set #3

Photo Information	Explanation	Photo Set #3
Location	Description of the location and directions to photo point	Yangtze River at the borders of the Deqin County, Wexi/Lisu County and Shangri-la County
GPS	Latitude-Longitude, Altitude	27°33"37.1" N-99.32.11.5" E, 2128 m
Orientation	Direction faced to retake photo (compass bearing)	348°
County	Political location of photo point	Deqin, Wexi/Lisu and Shangri-la County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, mixed forest, some woodlands/shrublands indicating timber extraction and grazing, montane conifer forest suspected at higher altitudes
Land Cover	Dominant vegetation	*Pinus yunnanensis/P. densata,* various deciduous spp., *Juglans* planted along river
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	Significant cultivation, no recent logging evident, pasture lands at higher altitudes
Infrastructure	Transportation, industrial and power infrastructure	Major roads present on river edges, religious temple on roadside and overlooking town, power lines present, border roadways (significant landscape degradation evident to put in power lines), some sort of power station/industry along river
Disturbance	Soil erosion, forest clearing, mining	Significant settlement build-up, mass wasting has occurred due to road construction, forest clearing for power infrastructure
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 3, 2008; 12:54 PM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Very cloudy, foggy - mountains and higher hills cannot be seen
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	Needed to find a clearing in mountainside vegetation in order to duplicate landscape characteristics present in original photograph - needed to move further to the left

Photo Set #8

Table B.3 Cataloging in-field photo information for Photo Set #8

Photo Information	Explanation	Photo Set #8
Location	Description of the location and directions to photo point	Yangtze River, in between Shang-ko-tzu and Tz'u-k'ai
GPS	Latitude-Longitude, Altitude	27°05"17.9" N-99.52.01.6" E, 1846 m
Orientation	Direction faced to retake photo (compass bearing)	317°
County	Political location of photo point	Lijiang and Shangri-la County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, mixed forest, some woodlands/shrublands indicating timber extraction, shrubland/grassland indicating degradation near river
Land Cover	Dominant vegetation	*Pinus yunnanensis/P. densata,* various deciduous spp., *Juglans* planted along river
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	Significant cultivation, no recent logging evident
Infrastructure	Transportation, industrial and power infrastructure	Major roads present on river edges, power lines present, border roadways
Disturbance	Soil erosion, forest clearing, mining	Significant settlement build-up, mass wasting has occurred due to road construction
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 3, 2008; 5:27 PM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Very cloudy, foggy, raining - mountains and higher hills cannot be seen
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	Time restraints wouldn't allow me to figure out a way to climb up onto the hill beside the road. The rock blasting that occurred for the road creation exposed cliffs all along the roadside with nowhere to climb up

Photo Set #14

Table B.4 Cataloging in-field photo information for Photo Set #14

Photo Information	Explanation	Photo Set #14
Location	Description of the location and directions to photo point	Yangtze River, at the foot of Haba Snow Mountain
GPS	Latitude-Longitude, Altitude	27°08"01.9"N-100°03.15.0"E, 1843m
Orientation	Direction faced to retake photo (compass bearing)	13°
County	Political location of photo point	Lijiang County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, mixed forest, alpine forest, alpine heath and meadow, shrubland/grassland (disturbed areas)
Land Cover	Dominant vegetation	*Pinus yunnanensis, P. densata, Juglans, Quercus spp.,* alpine spp.
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	Significant cultivation, grazing pasture, lots of forest resources available (suggests extraction of NTFPs and timber)
Infrastructure	Transportation, industrial and power infrastructure	Major roads present on all river edges, concrete supports and fill have been added recently to secure roads. Power lines/towers present
Disturbance	Soil erosion, forest clearing, mining	Significant settlement build-up in river confluence - may have been anthropogenically altered. Mass wasting events have occurred around roads, may have been human-induced.
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 13, 2008; 12:21 PM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Cloudy with a bit of sun (humid, hazy). I can hear thunder off in the distance. Haba Shan covered.
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	The roadway and riverside vegetation and the mountain being covered by clouds posed challenges for photographing the area (difficult to triangulate triangulation).

Photo Set #16

Table B.5 Cataloging in-field photo information for Photo Set #16

Photo Information	Explanation	Photo Set #16
Location	Description of the location and directions to photo point	Confluence of Chung-Chiang Ho and Yangtze River
GPS	Latitude-Longitude, Altitude	27°20"25.1"N-100°03.55.7"E, 1969 m
Orientation	Direction faced to retake photo (compass bearing)	192°
County	Political location of photo point	Lijiang County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Pine forest, looks like a plantation
Land Cover	Dominant vegetation	*Pinus yunnanensis, Alnus, Thuja, Betula, Quercus* and grassland
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	Significant cultivation, no recent logging
Infrastructure	Transportation, industrial and power infrastructure	Major roads present on all river edges, concrete supports and fill have been added recently to secure roads. Power lines present, border roadways
Disturbance	Soil erosion, forest clearing, mining	Significant settlement build-up in river confluence - may have been altered by humans. Mass wasting events have occurred around roads, may have been human-induced.
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 13, 2008; 2:22 AM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Cloudy with a bit of sun (humid, hazy). I can hear thunder off in the distance.
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	N/A

Photo Set #17

Table B.6 Cataloging in-field photo information for Photo Set #17

Photo Information	Explanation	Photo Set #17
Location	Description of the location and directions to photo point	Yangtze River, entering Tiger Leaping Gorge, Yulong Shan is on the right.
GPS	Latitude-Longitude, Altitude	27°10'25.2" N-100°04.29.3" E, 1996m
Orientation	Direction faced to retake photo (compass bearing)	27°
County	Political location of photo point	Lijiang County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, mixed forest, alpine forest, alpine heath and meadow, shrubland/grassland on the lower, steeper slopes
Land Cover	Dominant vegetation	Alpine spp. *(Rhododendron, Kobresia), Pinus densata, Abies, Picea, Pinus yunnanensis, Quercus spp.*, bamboo, shrubland and grassland spp.
Land Use	Anthropogenic alterations (logging, agriculture, grazing)	- No significant land use evident - grazing possible in the grasslands and shrublands of the lower slopes
Infrastructure	Transportation, industrial and power infrastructure	Trails along slopes, right slope shows a horizontal line with a pipe (carrying water?), roadways present along river's edge
Disturbance	Soil erosion, forest clearing, mining	Erosion along riverbank due to transportation infrastructure
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 13, 2008; 2:22 PM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Raining, cloudy, misty.
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	N/A

Photo Set #19

Table B.7 Cataloging in-field photo information for Photo Set #19

Photo Information	Explanation	Photo Set #19
Location	Description of the location and directions to photo point	Yangtze River, Tiger Leaping Gorge, Yulong Shan is on the right.
GPS	Latitude-Longitude, Altitude	27°10'37.2" N-100°05.01.8" E, 2160m
Orientation	Direction faced to retake photo (compass bearing)	24°
County	Political location of photo point	Lijiang County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, mixed forest, alpine forest, alpine heath and meadow, shrubland/grassland on the lower, steeper slopes
Land Cover	Dominant vegetation	Alpine spp. *(Rhododendron, Kobresia), Pinus densata, Abies, Picea, Pinus yunnanensis, Quercus spp.*, bamboo, shrubland and grassland spp.
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	Terraces for agriculture on left slope (hidden), pasture grazing possible in the grasslands and shrublands of the lower slopes
Infrastructure	Transportation, industrial and power infrastructure	Trails along slopes, right slope shows a horizontal line with a pipe (carrying water?), roadways present along river's edge, concrete transportation infrastructure protruding into river (erosion mitigation as well as parking lot/tourist information centre?)
Disturbance	Soil erosion, forest clearing, mining	Erosion along riverbank due to transportation infrastructure
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 13, 2008; 3:33 PM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Raining, cloudy, misty.
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	N/A

Photo Set #20

Table B.8 Cataloging in-field photo information for Photo Set #20

Photo Information	Explanation	Photo Set #20
Location	Description of the location and directions to photo point	Yangtze River, the central part of Tiger Leaping Gorge, looking upstream
GPS	Latitude-Longitude, Altitude	27°11'49.6" N-100°06.33.9" E, 2337m
Orientation	Direction faced to retake photo (compass bearing)	194°
County	Political location of photo point	Lijiang County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, *Quercus*/bamboo forest, mixed forest on higher slops across the river, shrubland/grassland on the lower, steeper slopes
Land Cover	Dominant vegetation	*Pinus yunnanensis, Quercus spp.*, bamboo, shrubland and grassland spp.
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	N/A
Infrastructure	Transportation, industrial and power infrastructure	Pipeline running horizontally along river slope, roadways present along river's edge, bridge built over mass wasting
Disturbance	Soil erosion, forest clearing, mining	Erosion along riverbank due to transportation infrastructure
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 14, 2008; 11:30 AM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Sunny (Fantastic)
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	N/A

Photo Set #21

Table B.9 Cataloging in-field photo information for Photo Set #21

Photo Information	Explanation	Photo Set #21
Location	Description of the location and directions to photo point	Yangtze River, the central part of Tiger Leaping Gorge, looking downstream
GPS	Latitude-Longitude, Altitude	27°11'50.9" N-100°06.38.9" E, 2400m
Orientation	Direction faced to retake photo (compass bearing)	11°
County	Political location of photo point	Lijiang County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, *Quercus*/bamboo forest, mixed forest on higher slopes across the river, shrubland/grassland on the lower, steeper slopes
Land Cover	Dominant vegetation	*Pinus yunnanensis, Quercus spp.*, bamboo, shrubland and grassland spp.
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	Potential for grazing (grasslands present)
Infrastructure	Transportation, industrial and power infrastructure	Pipeline running horizontally along river slope, roadways present along river's edge
Disturbance	Soil erosion, forest clearing, mining	Erosion along riverbank due to transportation infrastructure
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 14, 2008; 11:39 AM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Sunny (Fantastic)
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	The vegetation present made it difficult to retake the photograph from original photo point. Photo will be difficult to interpret.

Photo Set #22

Table B.10 Cataloging in-field photo information for Photo Set #22

Photo Information	Explanation	Photo Set #22
Location	Description of the location and directions to photo point	Yangtze River, near the end of Tiger Leaping Gorge, looking upstream
GPS	Latitude-Longitude, Altitude	27°15'04.2" N-100°08.46.0" E, 2431m
Orientation	Direction faced to retake photo (compass bearing)	179°
County	Political location of photo point	Lijiang County
Landscape Characteristics		
Ecoregions	Vegetation communities present	Warm *Pinus* forest, *Quercus*/bamboo forest, mixed forest on higher slopes across the river, shrubland/grassland on the lower, steeper slopes
Land Cover	Dominant vegetation	*Alpine spp. (Rhododendron, Kobresia), Pinus densata, Abies, Picea, Pinus yunnanensis, Quercus spp.,* bamboo, shrubland and grassland spp.
Land Use	Anthropogenic alterations (plantations, agriculture, grazing)	Potential for grazing (grasslands present)
Infrastructure	Transportation, industrial and power infrastructure	Pipeline running horizontally along river slope, roadways present along river's edge
Disturbance	Soil erosion, forest clearing, mining	Erosion along riverbank due to transportation infrastructure
Conditions		
Date and Time	A record of the date and time that the photo was retaken	June 14, 2008; 4:35 PM (UTC +8)
Air Quality	A record of the weather conditions and light quality	Raining
Difficulty with Shot	Reasons for inaccuracies, challenges with photo location	N/A

APPENDIX C:
PHOTO ANALYSIS
RECORDING VISIBLE LANDSCAPE CHANGES

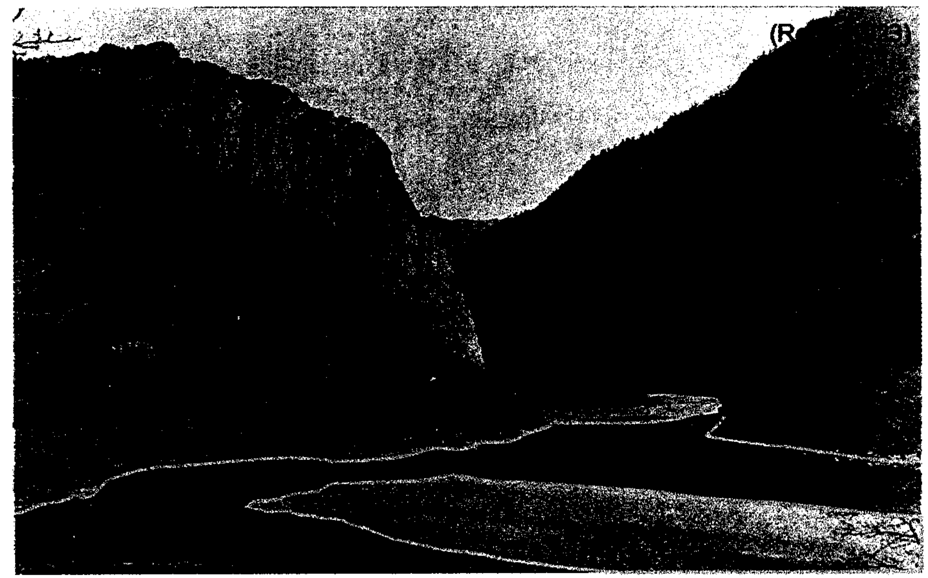
This appendix offers the reader an analysis of the visual landscape features that are evident in the photo pairs, as well as a description of the most prominent landscape changes. Identifying obvious landscape changes is the first step in photo analysis, as it quickly helps to target topics of more time-consuming, in-depth photo analysis. The landscape characteristics identified within the discussion are colour-coded according to the legend below.

Figure C.1 The legend for the colour-coded landscape classifications.

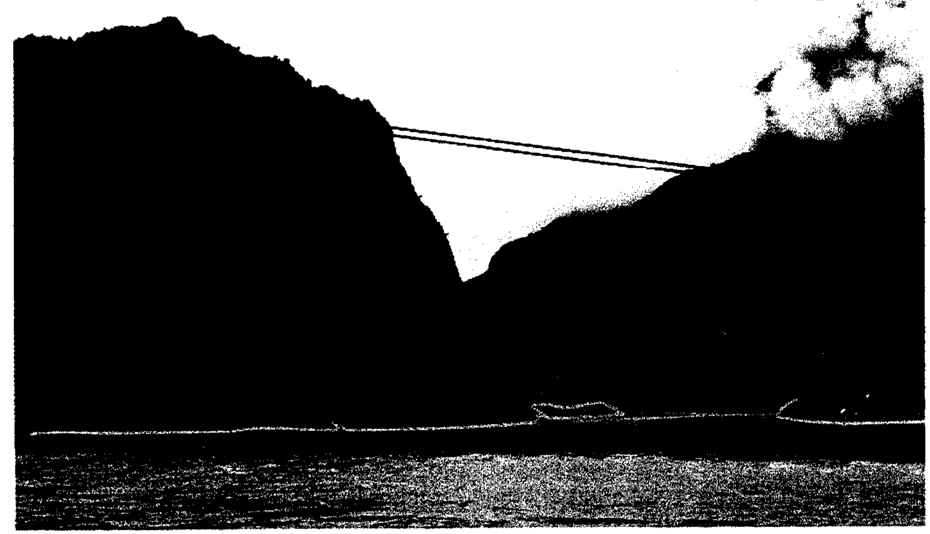
Landscape Classifications

- Residential/Commercial Infrastructure
- Transportation Infrastructure
- Industrial/Hydro Infrastructure
- Agricultural Lands
- Pasture Lands
- Forest Plantations
- Human-Impacted Vegetation
- Human-Induced Erosion
- Human-Impacted Wasteland
- Exposed Rock/Stable Soil
- Erosion/Mass Wasting
- Fluvial/Hydrology
- Fluvial Geomorphology
- Glaciers/Snow
- High-Altitude Geomorphology
- Arid Grassland
- Arid Shrubland
- Pinus Savannah
- Woodland
- Warm Pinus Forest
- Mixed Forest
- Evergreen Quercus Forest
- Evergreen Broadleaf Forest
- Subalpine Forest
- Alpine Heath/Alpine Meadow
- Undetermined
- Mixture of Landscape Classifications

Figure C.2 A list of qualitative landscape changes evident in Photo Set #1



(George, 2008)



Settlement
- The area occupied by housing and other buildings has not increased.

Transportation Infrastructure
- There is no transportation infrastructure evident in the historical photograph; however, in the recent photograph, paved roadways border every river bank.
- In the more recent photograph, significant erosion is present. This is a result of the newly implemented transportation infrastructure.

Industrial/Power Infrastructure
- Hydro wires and poles are present in the more recent photograph along the roadways.
- Major hydro towers and power lines have been added recently (since Moseley's photographs were taken in 2003).
- There is evidence of degradation to vegetation communities as a result of the implementation of power infrastructure.

Agricultural Lands
- In this photograph, there is no significant change to the area occupied by agricultural lands.

Fluvial
- No significant changes to fluvial hydrology or geomorphology are evident in this photo set.
- The water level is significantly higher in the recent photograph, indicating a seasonal variation in water level.

Human-Impacted Vegetation
- The riverbank vegetation has changed. The vegetation present along the river has increased. Where shrubs used to occupy the riverbanks, there are now deciduous trees, specifically *Juglans*.
- Evident in the photo set, the tree density has increased. Selective felling could have been used during the early 20th century, resulting in *Pinus* savannahs with a lower density of tree species. This change could also be related to changes in temperature and precipitation patterns over the past century (Climate Change).

Vegetation Communities
- The majority of forested areas seem to be warm *Pinus* forest.
- Mixed forest is also present in the more sheltered, moister areas.
- Tree density has greatly increased in forested areas (*Pinus* savannahs have changed to warm *Pinus* forests).

Settlement

- The area occupied by housing and other buildings has moderately increased.
- The density of buildings in settlement areas has also increased.
- There are two temples present in both photographs looking over the village.

Transportation Infrastructure

- There are paved roadways running along the Yangtze River on both banks.
- There is a large, 2-way bridge across the Yangtze River in the newer photograph in the center of the photographed landscape.
- Erosion due the implementation of transportation infrastructure is a prominent feature along the roadways of the recent photograph.

Industrial/Power Infrastructure

- Hydro wires and towers are present in the newer photograph.

Agricultural Lands

- The area occupied by agricultural lands has not increased. It may have decreased slightly.

Pasture Lands

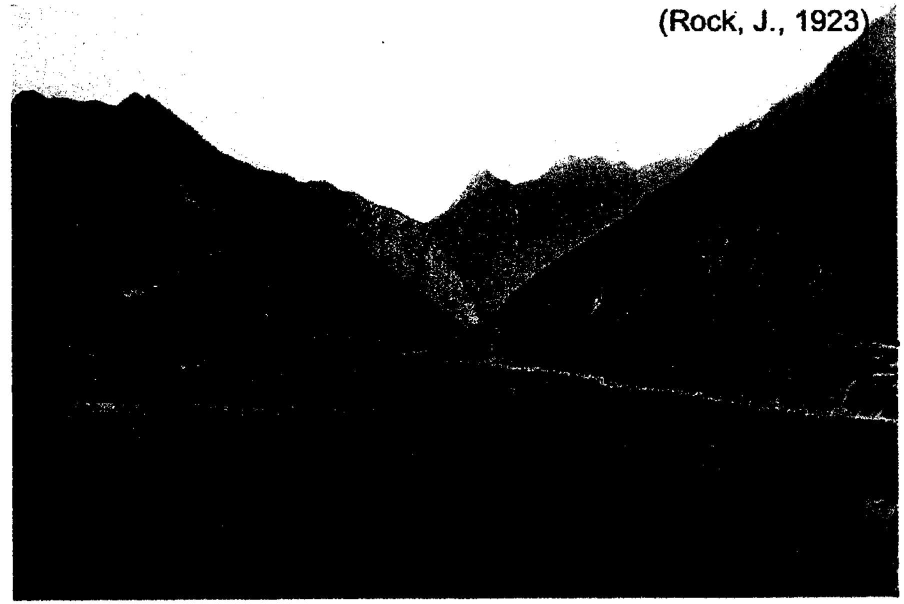
- Pasture lands appear to be present in both photographs at higher altitudes.
- The cleared area has not increased significantly, although there are more houses present.

Human-Impacted Vegetation

- There are deciduous trees, probably *Juglans* that have been planted, in between the agricultural fields.
- Riverbank vegetation has not changes significantly (mostly shrubland).

Vegetation Communities

- The majority of forested areas appear to be warm *Pinus* forest in both photographs.
- Mixed forest is also present in the more sheltered, moister areas.
- Subalpine conifer forest occurs at higher altitudes (mountains in the background).



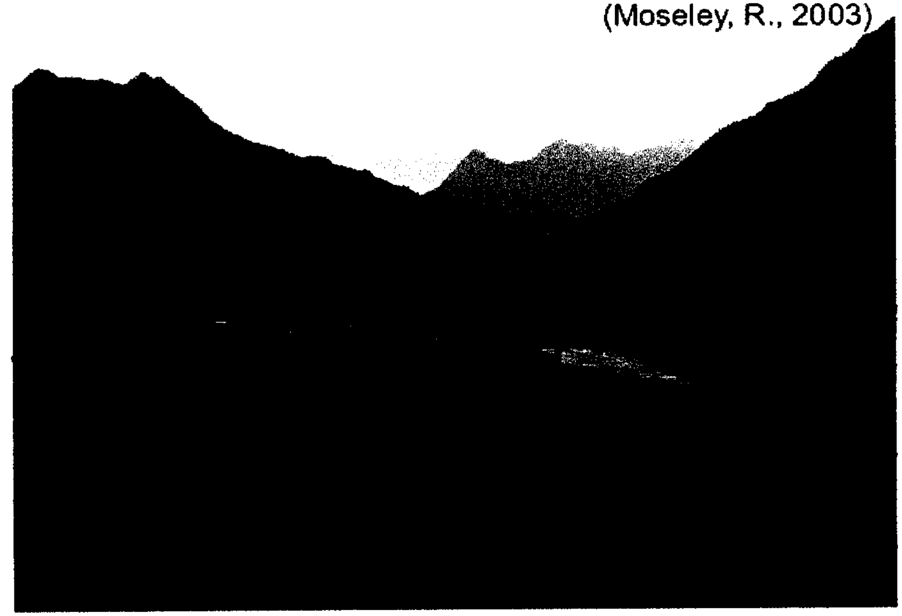


Figure C.3 Photographic evidence of landscape change in Photo Set #2

Figure C.4 Photographic evidence of landscape change in Photo Set #3

Settlement

- The area occupied by settlement area has increased in both size and density.
- There are 2 temples evident in each photograph in the mountains overlooking the valley.

Transportation Infrastructure

- There are very few transportation routes evident in the historic photograph. In contrast, there are significant paved roadways running along both sides of the Yangtze River in the new photograph, as well as a bridge running over the river.

Industrial/Power Infrastructure

- Hydro wires and towers are present in the newer photograph.
- There is a power generating station in the middle-right of the recent photograph with major power lines and towers running out of it.

Agricultural Lands

- The area occupied by agricultural lands has decreased during the period between photographs.
- Much of the area previously occupied by agricultural lands is now occupied by deciduous forest.

Fluvial

- There have been no significant changes to the river hydrology or geomorphology, based on the photo pair.
- There is evidence of seasonal variation in water level (water levels are higher in the more recent photograph that was taken during the summer).

Human-Impacted Vegetation

- Riverbank vegetation has increased significantly. It was likely planted (*Juglans*) to mitigate riverbank erosion.
- Tree density appears to be lower in the forested areas in the historical photograph. Selective felling could have been used during the early 20th century, resulting in lower density *Pinus* savannahs and woodlands. This could also be related to changes in temperature and precipitation.

Vegetation Communities

- The majority of forested areas appear to be warm *Pinus* forest in both photographs.
- Mixed forest is also present in the more sheltered, moister areas.

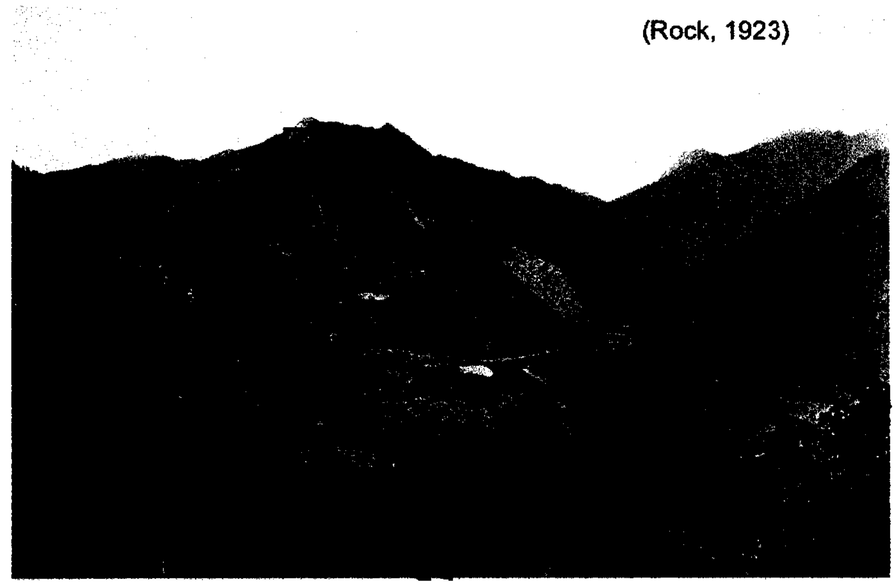
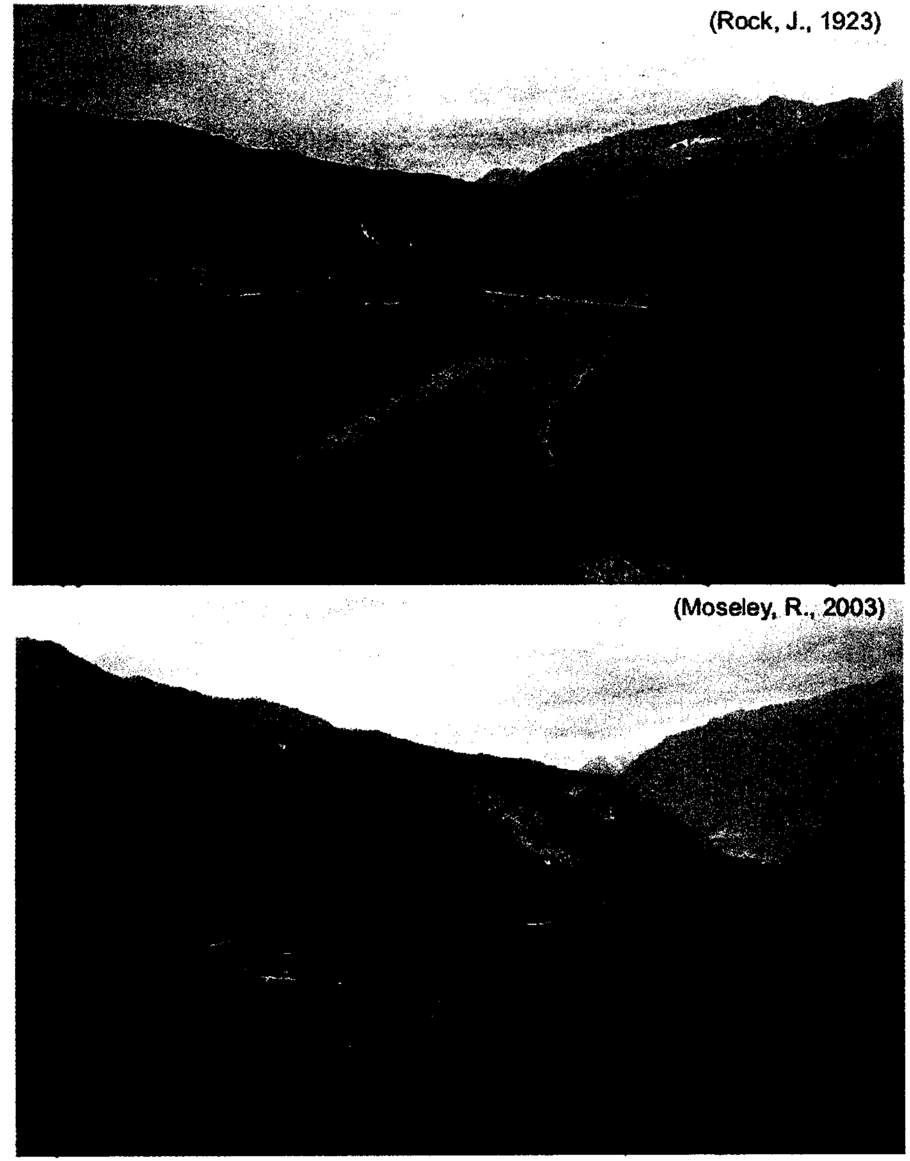


Figure C.5 Photographic evidence of landscape change in Photo Set #4



Settlement

- The area occupied by housing and other buildings has significantly increased.
- The density of buildings in settlement areas has also increased.

Transportation Infrastructure

- While pronounced dirt pathways are seen running along the left bank in the historic photograph, paved roadways running along the Yangtze River are present on both banks in the recent photograph.

Industrial/Power Infrastructure

- Hydro wires and towers are present in the newer photograph.

Agricultural Lands

- In this photo pair, there is no significant change in the area occupied by agricultural lands.

Fluvial

- There are no significant changes to river hydrology or geomorphology evident in this photo set.

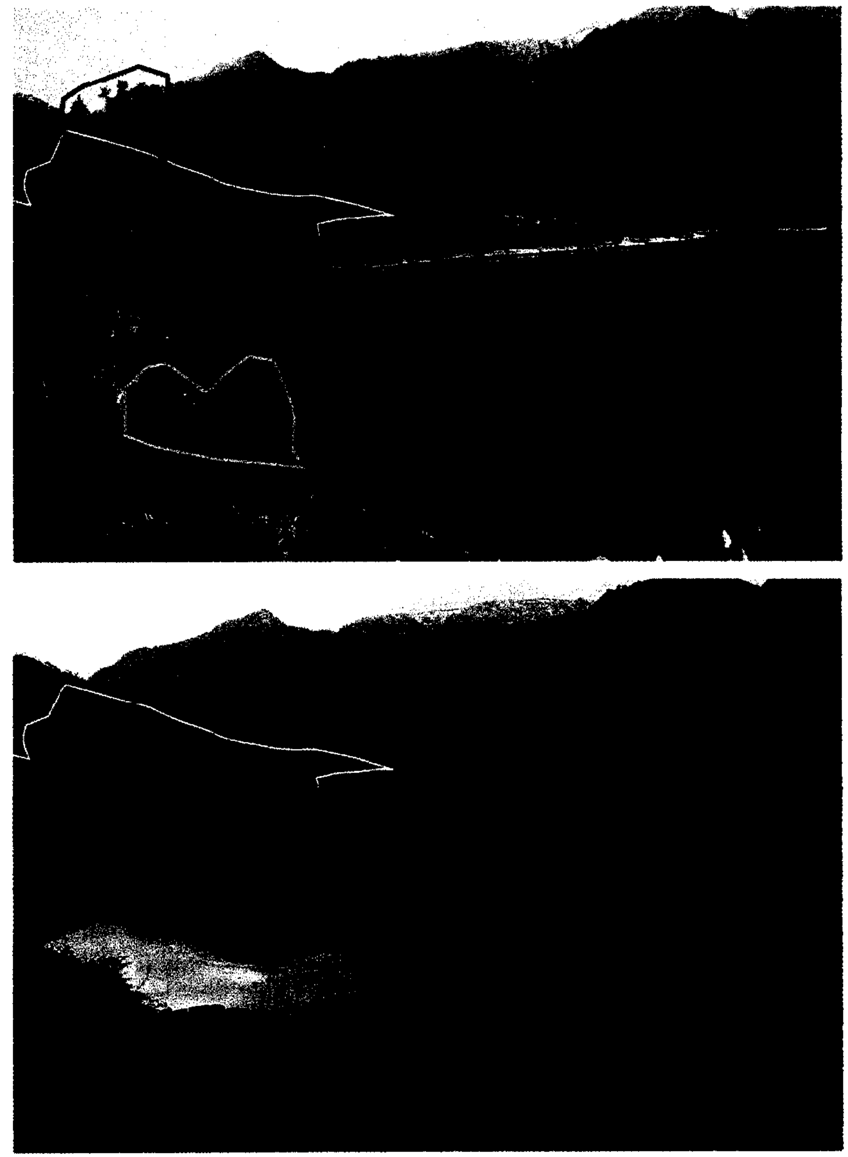
Human-Impacted Vegetation

- Riverbank vegetation has not changed significantly (shrubland).
- There is evidence of deforestation in the historical photograph in the upper left-hand corner.
- Selective felling could have been used during the early 20th century, resulting in lower-density *Pinus* savannahs and woodlands (outlined in green on the right side of the historical photograph), as the tree density of the forested areas has greatly increased over the past 100 years. This could also be related to changes in climate.

Vegetation Communities

- The majority of forested areas appear to be warm *Pinus* forest in both photographs.
- Mixed forest is also present in the more sheltered, moister areas.
- Tree density has greatly increased in forested areas (*Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph).

Figure C.6 Photographic evidence of landscape change in Photo Set #5



Overall, there are no significant landscape changes evident in this photo set.

Settlement
- The area occupied by housing and other buildings has not increased.
- There is no evidence of a high population.

Transportation Infrastructure
- There are no roadways are evident in the historic photograph. There are paved roadways running along the right bank of the Yangtze River in the recent photograph.

Industrial/Power Infrastructure
- Hydro poles are present in the newer photograph along the roadway.

Agricultural Lands
- There have been no significant changes to the area occupied by agricultural lands on the left bank of the Yangtze River.
- The agricultural lands that were present on the right bank of the Yangtze River in the historical photograph have since been abandoned.

Fluvial
- There are no significant changes to river hydrology or geomorphology evident in this photo set.
- The notable amount of fluvial geomorphology exposed in both photographs suggests a drastic change in seasonal water levels.

Human-Impacted Vegetation
- Riverbank vegetation has not changed significantly (shrubland).
- *Pinus* is present in the foreground of both photographs.

Vegetation Communities
- The majority of forested areas appear to be warm *Pinus* forest in both photographs.
- Mixed forest is also present in the more sheltered, moister areas.
- Subalpine conifer forest is probably occurring on the higher slopes of the mountains in the background of both photographs.
- There is arid grassland/woodland on the left side of the river (shown in light green) that looks to have been converted into woodland or sparse *Pinus* forest by the more recent photograph.
- Tree density has greatly increased in the forested areas (the *Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph).

Figure C.7 Photographic evidence of landscape change in Photo Set #6

Settlement

- The area occupied by housing and other buildings has increased slightly.

Transportation Infrastructure

- Where dirt pathways existed in 1923, paved roadways are evident in 2003 (running along the right bank of the Yangtze River)

Industrial/Power Infrastructure

- Hydro poles are present in the newer photograph along the roadway.

Agricultural Lands

- There has been no significant change to the area occupied by agricultural lands.

Fluvial

- Significant changes to river hydrology and geomorphology suggest a lower water level, as well as turbulent waters.
- The vegetation occurring on the islands suggest that they are unstable (seasonally submerged)

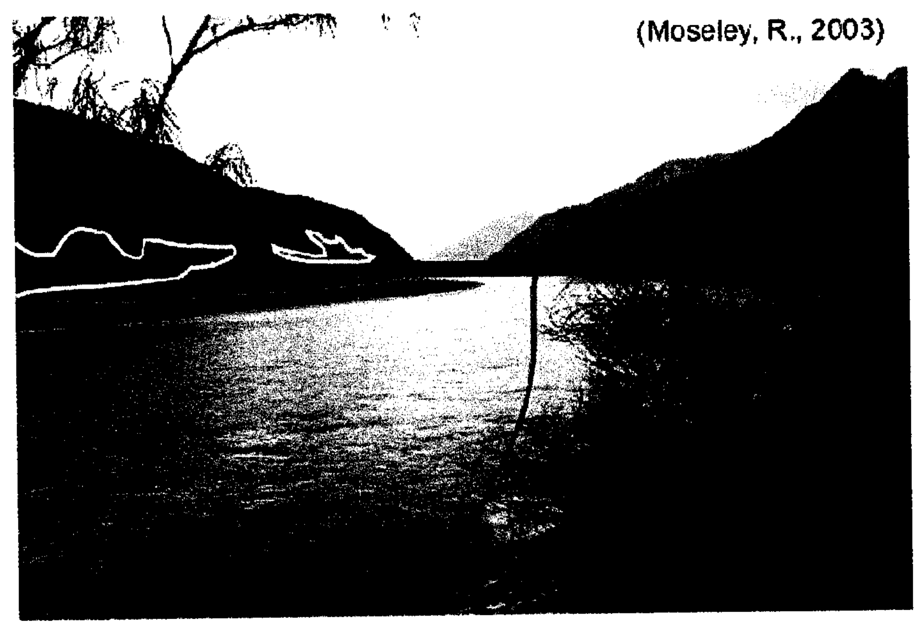
Vegetation Communities

- There are grasslands occurring below the treeline in the background of the photograph. This may be due to deforestation or grazing, but this cannot be confirmed.
- The majority of forested area appears to be warm *Pinus* forest.
- Mixed forest is suspected to be present in the moister, more sheltered areas.
- Tree density has increased significantly. *Pinus* savannahs and woodlands have become *Pinus* forests.

Figure C.8 Photographic evidence of landscape change in Photo Set #7

(Rock, J., 1923)

(Moseley, R., 2003)



Settlement
- The area occupied by housing and other buildings has not increased.

Transportation Infrastructure
- There is a pathway present along the right bank of the Yangtze River in the historic photograph. That pathway has been changed into a paved roadway by 2003.

Industrial/Power Infrastructure
- There are two hydro poles evident in the newer photograph, suggesting that the power line is following the road.

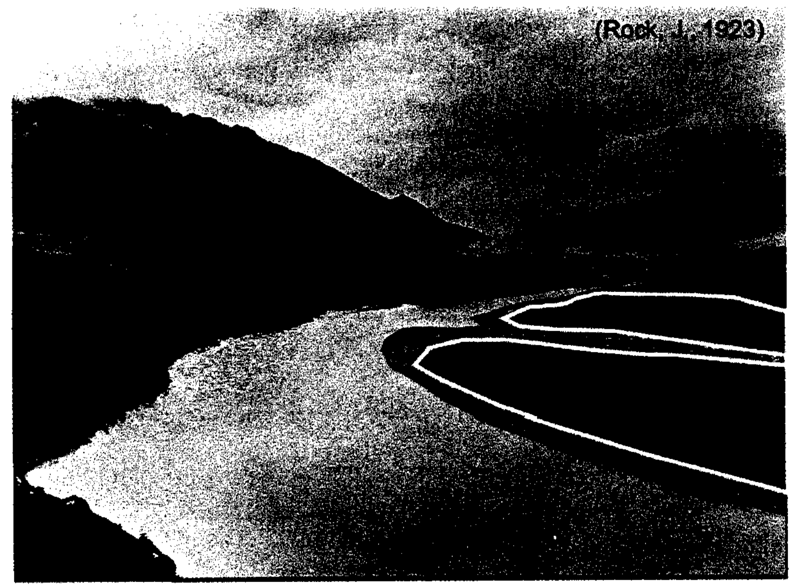
Agricultural Lands
- Agricultural lands are present in both photographs; however, because of the photo point, it is difficult to see the extent of the agricultural lands.

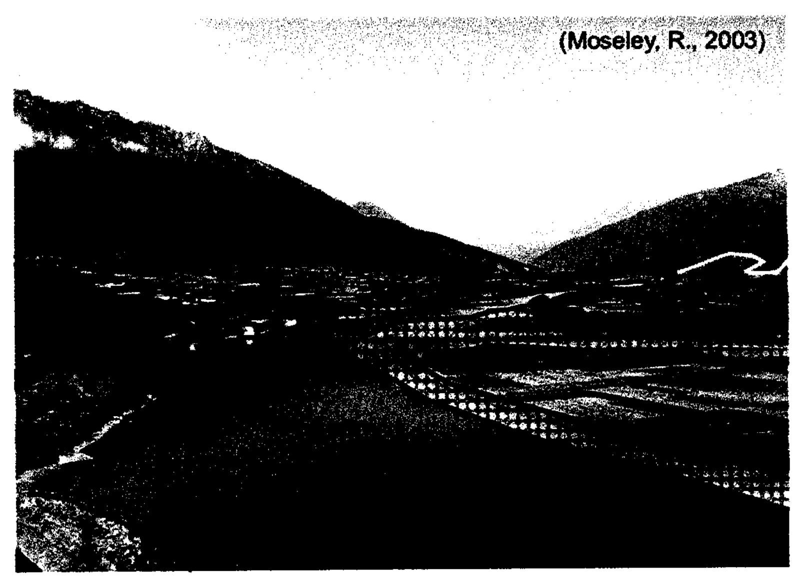
Fluvial
- The exposed fluvial geomorphology has increased, suggesting lower water levels.

Human-Impacted Vegetation
- There has been a significant increase in the presence of riverbank vegetation from 1923 to 2003. Although I cannot confirm that the vegetation was planted by humans, I assume that it was done by humans to combat the erosion that is evident in the historic photograph.

Vegetation Communities
- The majority of forested areas appear to be warm *Pinus* forest.
- Tree density has greatly increased in the forested areas (the *Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph).
- Areas of woodland/*Pinus* savannah are evident in both photographs. The area is larger in the historical photograph. The reason for the presence of this vegetation community is unclear (either climatic or caused by harvesting/grazing).

Figure C.9 Photographic evidence of landscape change in Photo Set #8





Settlement
- The area occupied by settlement has increased significantly.
- The settlement has become more densely populated with houses.

Transportation Infrastructure
- Roadways are evident on the left bank of the Yangtze River in the recent photograph. No road infrastructure can be seen in the historical photograph, but I suspect that substantial dirt pathways are present.

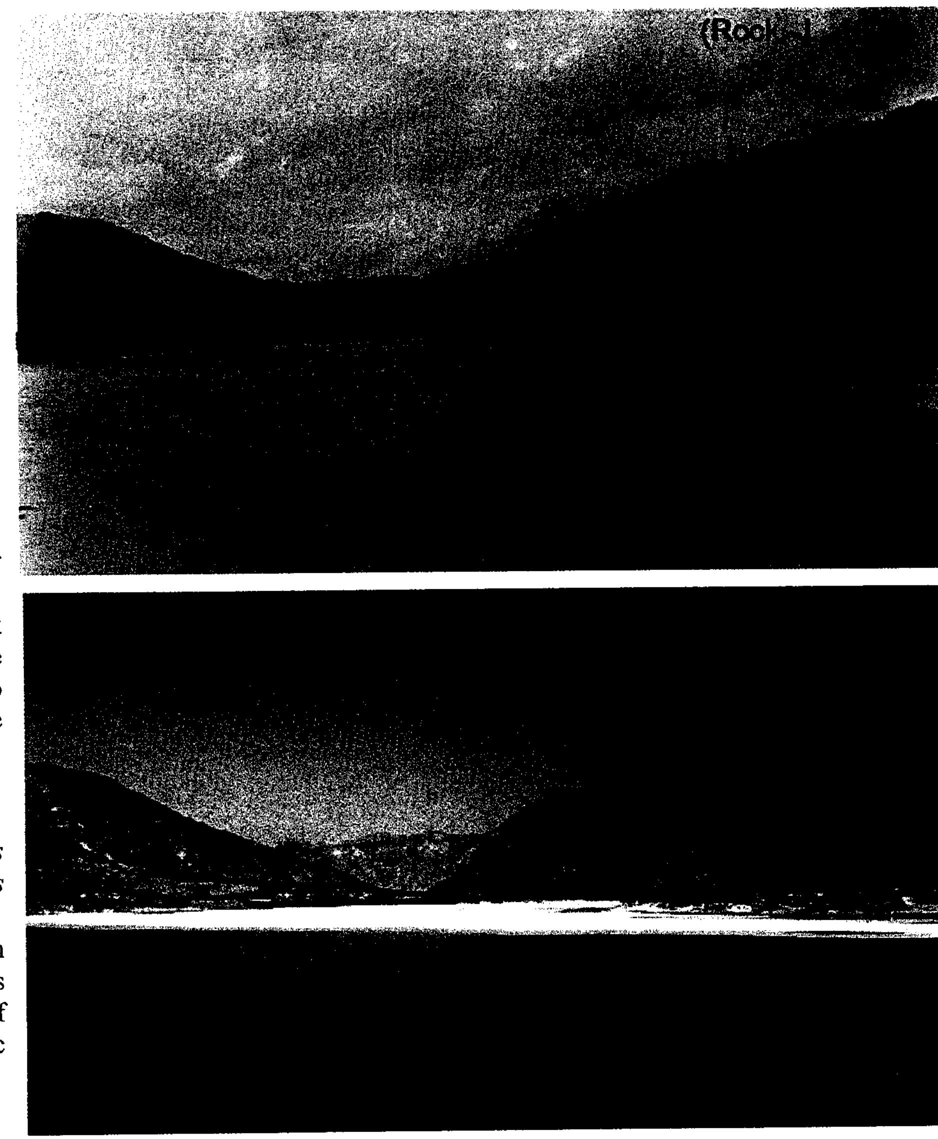
Industrial/Power Infrastructure
- Hydro lines are present in the newer photograph running along the roadway.

Agricultural Lands
- Agricultural lands are present in both photographs; however, because of the mist in the historical photograph, it is difficult to determine the extent of the area occupied by agricultural lands. I think that the area occupied by agricultural lands has stayed about the same over the past century. The fluvial island has been converted from grassland to agricultural land.

Fluvial
- The amount of exposed fluvial geomorphology has increased, suggesting lower water levels.
- Riverbank vegetation has greatly increased. Although I cannot confirm it, I believe that the vegetation was planted by humans in an effort to combat erosion.

Vegetation Communities
- The majority of forested areas appear to be warm *Pinus* forest.
- Mixed forest is also present in the more sheltered, moister areas.
- Tree density has greatly increased in the forested areas (the *Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph).
- The areas bordering settlements seem to be degraded in the recent photograph (erosion/wastelands)

Figure C.10 Photographic evidence of landscape change in Photo Set #9



Settlement

- The area occupied by settlement has significantly increased and the settlement pattern has become denser.

Transportation Infrastructure

- Roadways are evident on both sides of the river in Moseley`s photograph. No road infrastructure can be seen in Rock`s photograph, but I suspect that dirt pathways are present.

Industrial/Power Infrastructure

- Hydro lines are present in the newer photograph running along the roadway on the right side of the river.

Agricultural Lands

- Agricultural lands are present in both photographs; however, because of the photo point, it is difficult to see the extent of the agricultural lands. I think that the areas occupied by agricultural lands have decreased significantly within the time period between when the photographs were taken.

Fluvial

- Exposed fluvial geomorphology has increaseed, suggesting lower water levels.
- There has been a significant increase in the presence of riverbank vegetation from 1923 to 2003. Although I cannot confirm that the vegetation was planted by humans, I assume that it was done to combat the erosion that is evident along the riverbanks in the historic photograph.

Vegetation Communities

- The majority of forested areas appear to be warm *Pinus* forest.
- Tree density has greatly increased in the forested areas (the *Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph).
- Areas of woodland/*Pinus* savannah are evident in both photographs. The area occupied by these vegetation communities is larger in the historic photograph. The reason for the presence of these vegetation communities is unclear. It could be either climatic or caused by harvesting/grazing.

Settlement

- The areas occupied by settlements have moderately increased.
- The density of buildings in the settlement areas has increased.

Transportation Infrastructure

- A paved roadway running along the right bank of the Yangtze River is present in the recent photograph.
- Erosion is prominent along the roadway (human-induced) in the newer photograph.

Industrial/Power Infrastructure

- Hydro lines are present in the more recent photograph running along the roadway.

Agricultural Lands

- The agricultural lands present in the historical photograph have since been converted to settlement.
- The flat land on the left bank of the river could be used for agricultural/grazing lands, but it is difficult to determine from the photograph , as the photo point does not allow for a good angle and the land is covered by the riverbank vegetation in the newer photograph.

Pasture Lands

- The flat land on the left bank could be used for pasture lands.
- The lower slopes of the left bank (facing south) could also serve as grazing pasture, as the vegetation community occupying that area is arid grassland. No significant change to this vegetation community is evident from this photo pair.

Fluvial

- Water levels seem to be slightly lower in the more recent photograph.
- Riverbank vegetation has increased significantly on the left bank, but it has been reduced on the right bank because of the development of road infrastructure.

Vegetation Communities

- Arid grasslands are prominent on the lower, south-facing slopes (climatic).
- The majority of forested areas seem to be warm *Pinus* forest with mixed forest present in the more sheltered, moister areas.
- Tree density has greatly increased in the forested areas (the *Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph).

Figure C.11 Photographic evidence of landscape change in Photo Set #10

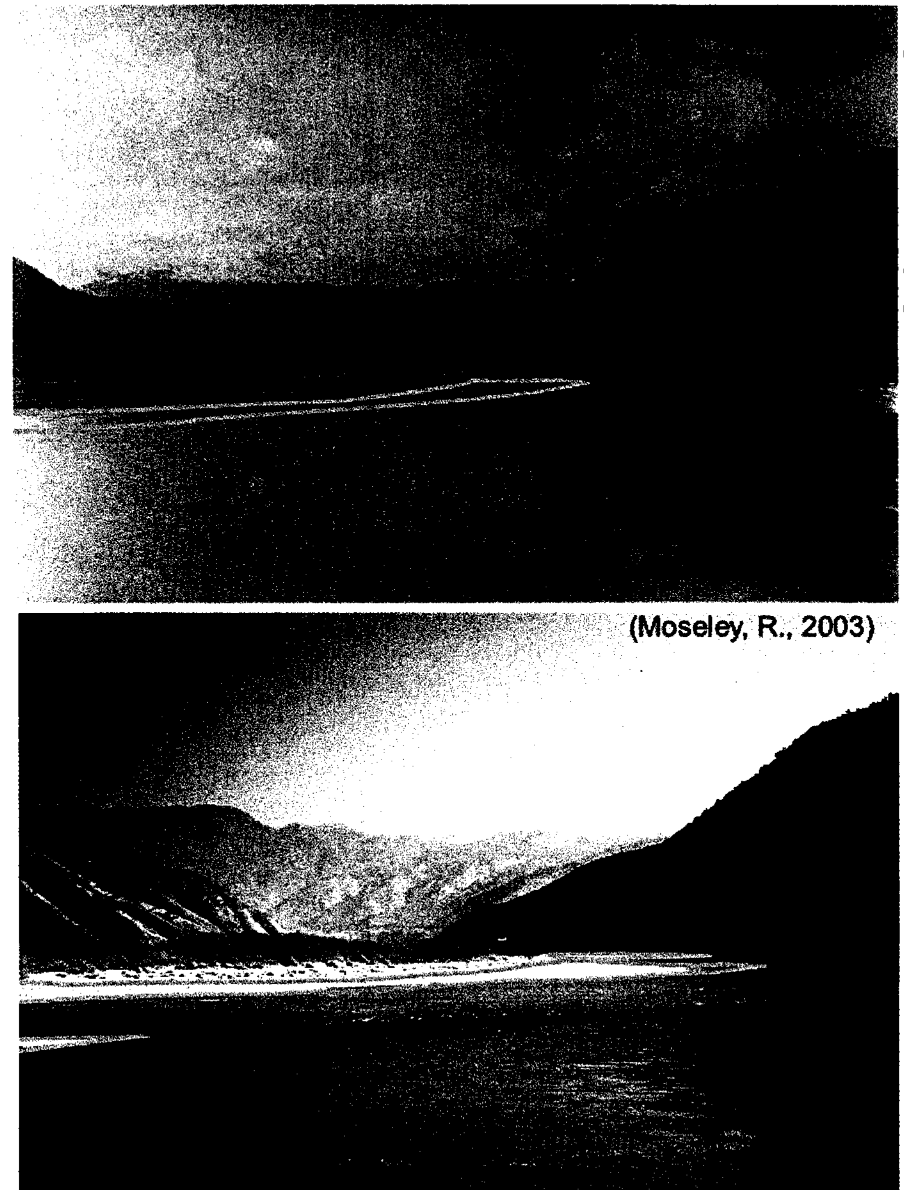


Figure C.12 Photographic evidence of landscape change in Photo Set #11

Settlement
- The area occupied by housing and other buildings has moderately increased.
- The density of the settlement pattern has increased.

Transportation Infrastructure
- There are paved roadways running along both sides of the Yangtze River in the more recent photograph.
- Erosion is prominent along the roadways (human-induced) in the more recent photograph.

Industrial/Power Infrastructure
- Hydro wires and hydro towers are present in the more recent photograph.

Agricultural Lands
- The area occupied by agricultural lands seems rather stable/may have decreased slightly.

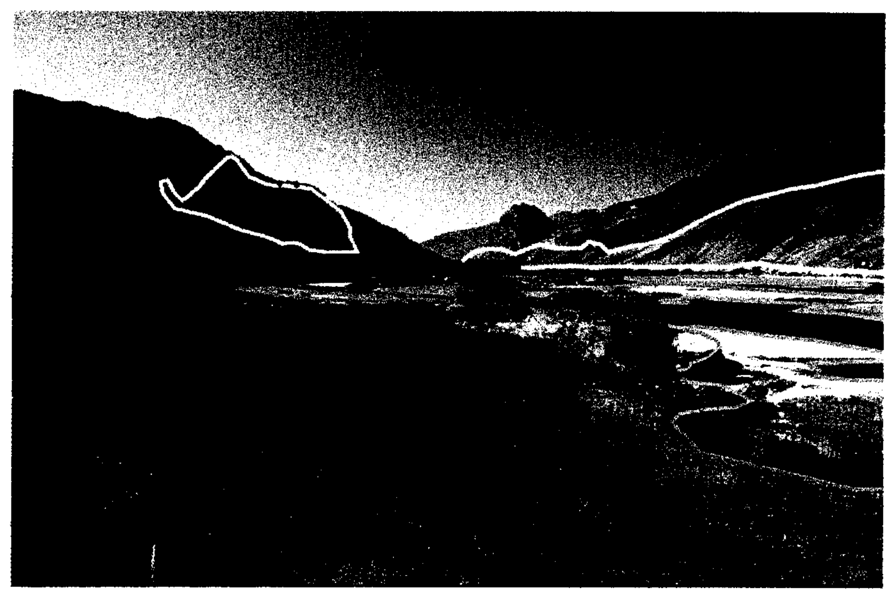
Pasture Lands
- It is possible that pasture lands may exist on the flat areas and lower slopes on the right side of the Yangtze River where grassland is the primary vegetation community. This exists in both photographs.

Fluvial
- Water levels are low in both photographs. A permanent island has developed by 2003 in the foreground of the photo pair. There is a mature tree growing on the island, suggesting that this soil is always exposed (above the water level). There are also grass tufts growing on the island.
- The riverbank vegetation on the right bank of the Yangtze River has changed significantly. Where there was no vegetation growing in the historical photograph, there are mature trees growing in 2003. They look to be deciduous (*Alnus, Populus*)

Vegetation Communities
- The majority of forested areas appear to be warm *Pinus* forest.
- Mixed forest is also present in the more sheltered, moister areas.
- Tree density has greatly increased in the forested areas (indicated in dark green). The *Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph.

Figure C.13 Photographic evidence of landscape change in Photo Set #12

(Rock, J., 1923)



Settlement
- The area occupied by housing and other buildings has moderately increased.
- The density of buildings within settlement areas has also increased.

Transportation Infrastructure
- The dirt pathway running along the left bank of the Yangtze River in the historical photograph has been converted to a paved roadway by 2003.
- Erosion due to new transportation infrastructure can be seen in the background of the recent photograph on the left riverbank of the Yangtze River.

Industrial/Power Infrastructure
- Hydro lines are present in the more recent photograph running along the road, as well as on the top of the hill overlooking the town.

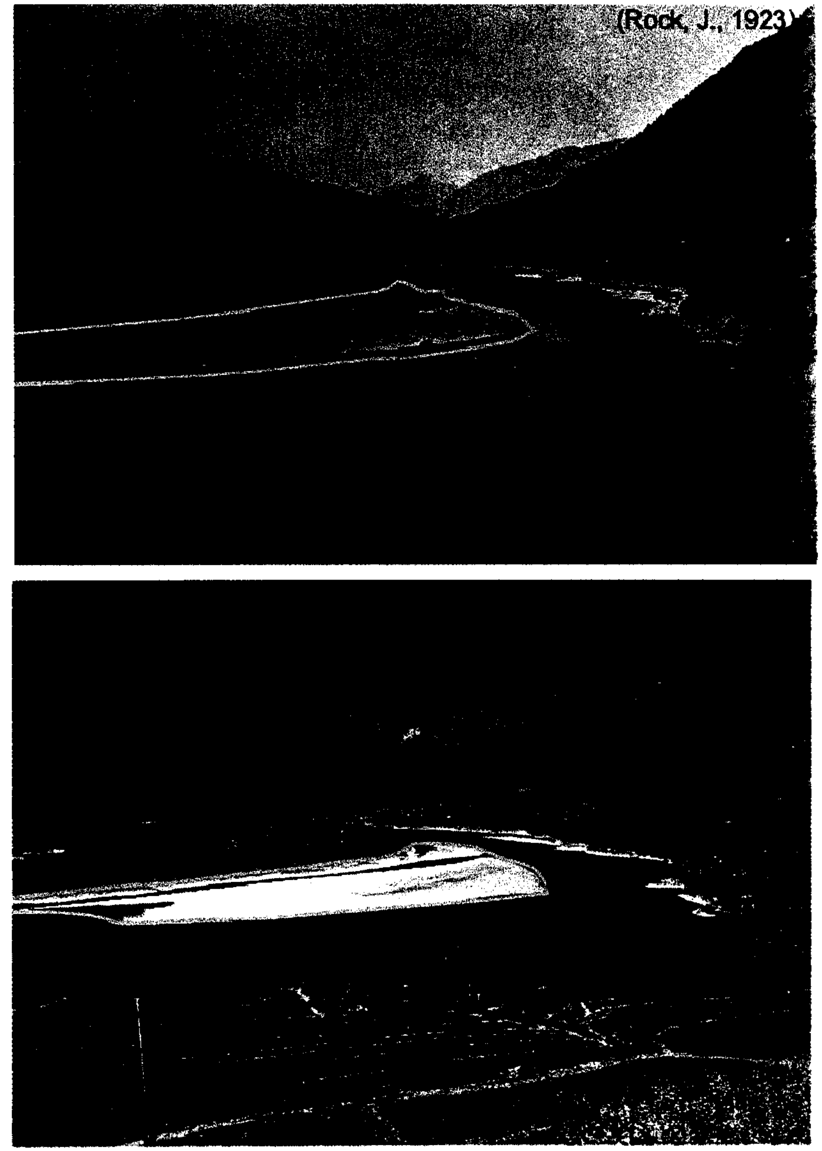
Agricultural Lands
- Agricultural lands have decreased slightly.

Pasture Lands
- The arid grasslands that are prominent on the south-facing slopes at lower altitudes in both photographs (outlined in light green) could serve as grazing land.

Fluvial
- There have been drastic changes to the fluvial geomorphology during the time interval in between photographs. There is a new landmass in the foreground of Moseley`s photograph that didn`t exist when Rock took his photograph. The landmass must be a stable part of the environment, as there are mature trees (about 20 years) growing on the land, as well as many shrubs.
- The water level is low in both photographs, exposing seasonal islands.

Vegetation Communities
- The majority of forested areas appear to be warm *Pinus* forest in both photographs.
- Mixed forest is also present in the more sheltered, moister areas.
- Tree density has greatly increased in forested areas (*Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph).

Figure C.14 Photographic evidence of landscape change in Photo Set #13



Settlement
- The area occupied by housing and other buildings has not increased.

Transportation Infrastructure
- Paved roadways running along both banks of the Yangtze River are present in the 2003 photograph
- Erosion is prominent along roadways (human-induced) in the newer photograph. It is evident on the left bank in the background of Moseley's photograph.

Industrial/Power Infrastructure
- Hydro wires and poles are present in the newer photograph running along both sides of the Yangtze River.

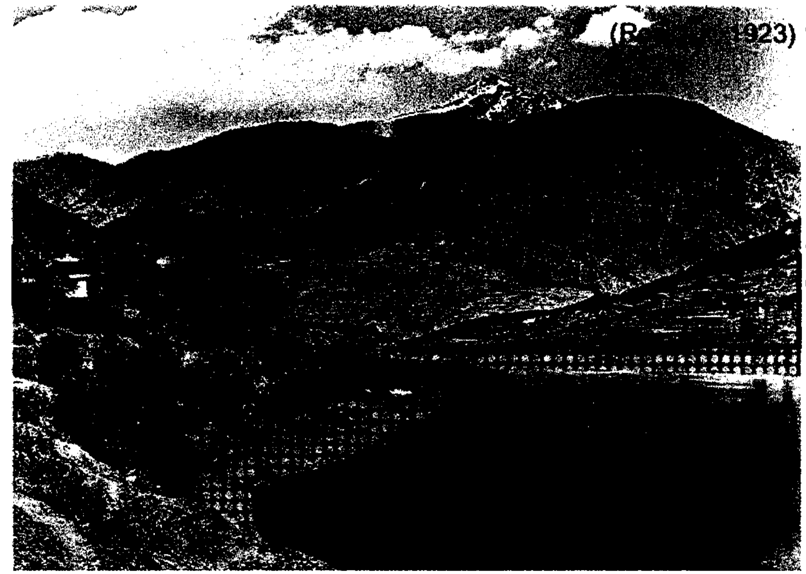
Agricultural Lands
- Agricultural Lands have decreased slightly.

Fluvial
- There are no significant changes to river hydrology or geomorphology evident in this photo set.

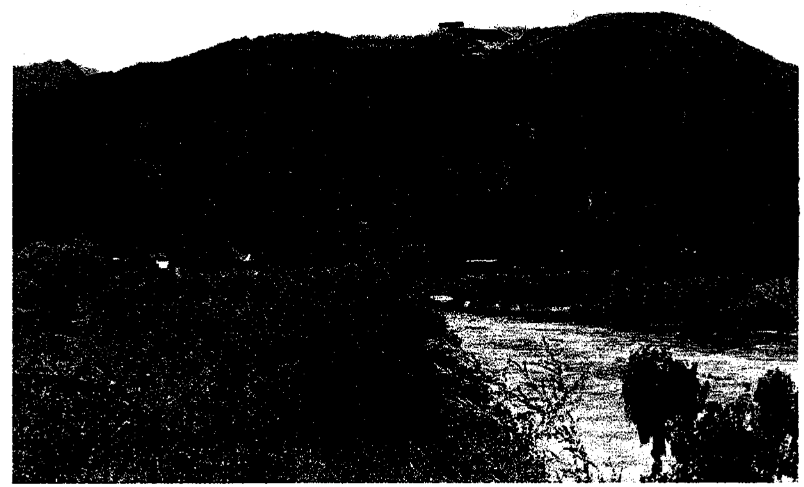
Human-Impacted Vegetation
- Riverbank vegetation has significantly increased. Much of the riverbank vegetation on the right bank looks to have generated naturally; however, the vegetation on the left bank look to have been planted by humans.

Vegetation Communities
- The majority of forested areas appear to be warm *Pinus* forest in both photographs.
- Mixed forest is also present in the more sheltered, moister areas.
- Subalpine conifer forest is present at higher altitudes (mountains in the background)
- Tree density has greatly increased in forested areas (*Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph).

Figure C.15 Photographic evidence of landscape change in Photo Set #14



(George, C., 2008)



Settlement
- Areas occupied by settlements have increased in both size and density.

Transportation Infrastructure
- Only a dirt pathway is visible in the 1923 photograph. In 2008, paved roadways ran along both banks of the Yangtze River. As well, there were many secondary roads joining the main roadways to the nearby settlements.
- Erosion is prominent along roadways (human-induced) in the newer photograph.

Industrial/Power Infrastructure
- Hydro poles and power lines are present in newer photograph running along the roadways. There are also massive hydro towers running power lines across Haba Shan. This infrastructure is very new, as it was not present in Moseley`s photograph, taken in 2003.

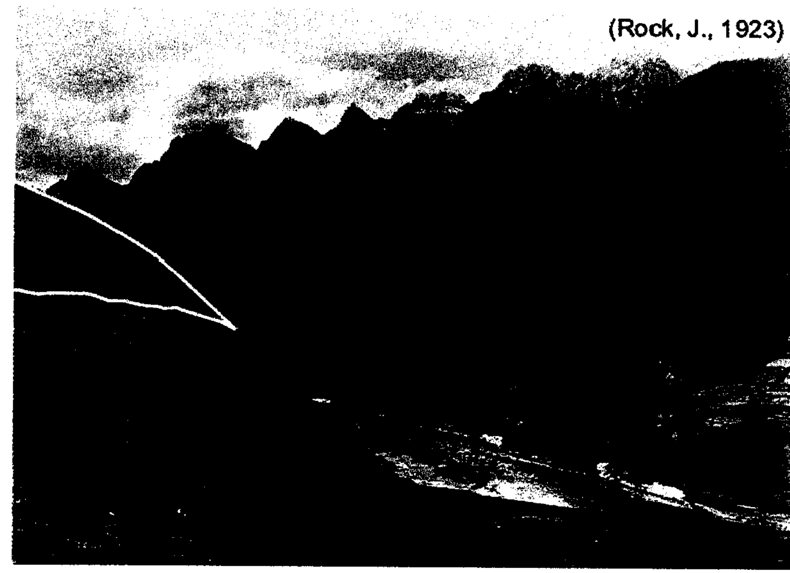
Agricultural Lands
- The agricultural lands in this area have decreased over the past century.

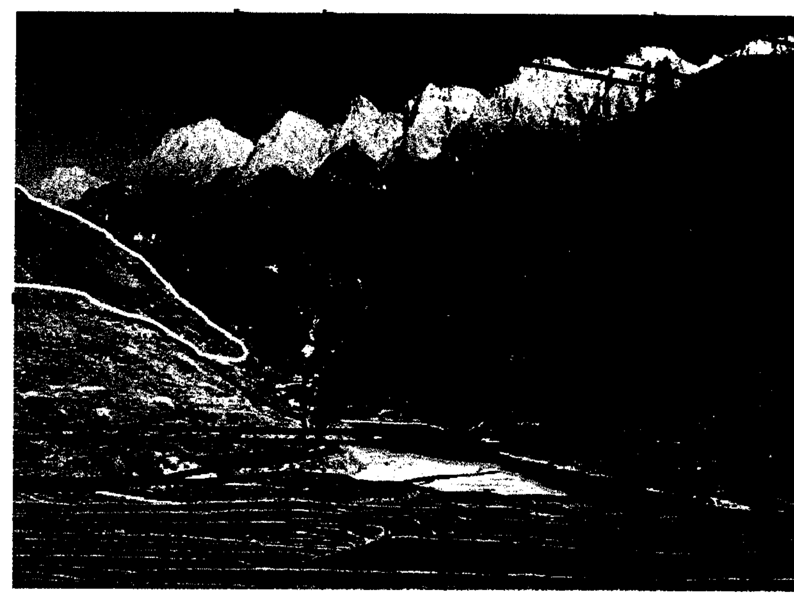
Pasture Lands
- Grazing pasture has decreased in the lower altitudes over the past century. A significant portion of the arid grassland present in 1923 has been converted to woodland or forest. At higher altitudes, the potential grazing pasture appears to have increased, as there are more alpine meadows evident in the more recent photograph.

Human-Impacted Vegetation
- There has been a significant increase in the presence of riverbank vegetation. There is evidence of significant riverbank erosion in the historical photograph. By 2008, mature deciduous trees over the riverbanks. I believe that they were planted by humans to mitigate the riverbank erosion.

Vegetation Communities
- This photograph displays a variety of vegetation communities, including arid grasslands, arid shrublands, woodlands, warm *Pinus* forest, mixed forests, subalpine forests and high-altitude meadows.

Figure C.16 Photographic evidence of landscape change in Photo Set #15





Settlement

- The area occupied by settlements has increased in both area and density.

Transportation Infrastructure

- In the historical photograph, there is very little evidence of transportation infrastructure. There is evidence of a pathway across the upper bank on the right side of the Yangtze River. There is also evidence of a dirt roadway leading to one of the houses. In 2003, there were paved roadways running along the Yangtze River on both banks, as well as secondary roads branching off of these main roads and leading into the settlements.
- There is notable erosion along the right bank of the Yangtze River. This is due to the new transportation infrastructure.

Industrial/Power Infrastructure

- Hydro poles and towers are present in newer photograph running along the roadways.

Agricultural Lands

- Agricultural lands have not increased. They have decreased slightly.

Pasture Lands

- Grazing pasture looks to be present at higher altitudes on the left bank in both photographs.
- Livestock is present in the lower right corner of Rock`s photograph (cows). They look to be grazing on agricultural lands.

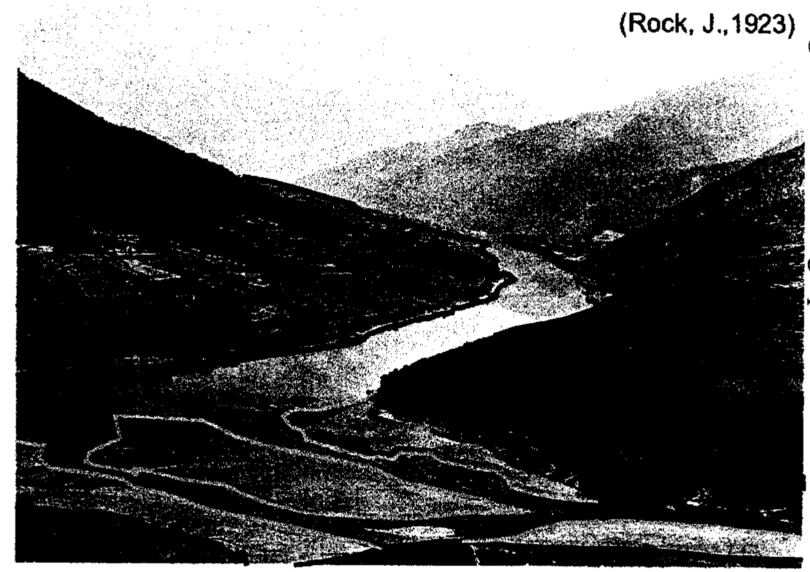
Human-Impacted Vegetation

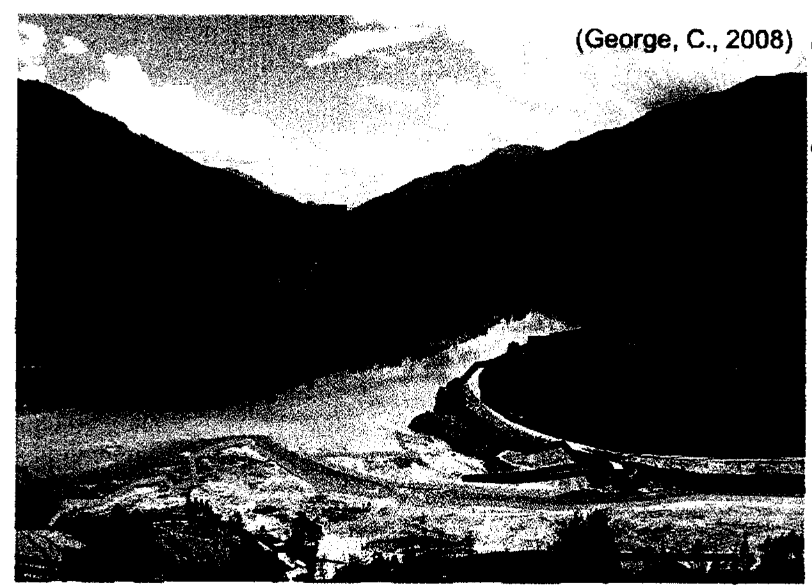
- There is evidence of crop field abandonment and regrowth. Also, there seems to be evidence of selective felling in both photographs based on tree density.

Vegetation Communities

- The majority of forested areas appear to be warm *Pinus* forest in both photographs.
- Mixed forest is also present in the more sheltered, moister areas.
- Subalpine conifer forest is present at higher altitudes.
- Tree density has greatly increased in forested areas (*Pinus* woodlands present in the historical photograph are warm *Pinus* forests in the recent photograph).

Figure C.17 Photographic evidence of landscape change in Photo Set #16





Settlement
- Both the area and density of settlements has increased.

Transportation Infrastructure
- In the 1923 photograph, there is evidence of transportation infrastructure. There are dirt pathways along the riverbanks on both sides of the Yangtze River. By 2008, there are paved roadways running along the Yangtze River on both banks, as well as secondary roads branching off of these main roads and leading into the settlements.

Industrial/Power Infrastructure
- Hydro lines are present in the newer photograph running along the roadways.
- Evident in the newer photograph, clearings have been cut within the forest on the left bank to allow for a hydro line to pass through. This has been done since Moseley conducted his rephotography study from 2003-2005.

Agricultural Lands
- Agricultural lands have decreased significantly and *Pinus* forests have grown in the abandoned agricultural lands.

Pasture Lands
- The lands bordering the agricultural lands on the right bank could have been used for grazing in 1923. The area has since become forested.

Human-Impacted Vegetation
- There is evidence of crop field abandonment and regrowth.
- There is evidence of riverbank erosion in 1923. This has since been mitigated by riverbank vegetation. I suspect that this was done by humans.

Vegetation Communities
- The majority of forested areas appear to be warm *Pinus* forest in both photographs. The area occupied by warm *Pinus* forest has increased as peripheral agricultural lands have been abandoned.
- Mixed forest is also present in the more sheltered, moister areas.
- Tree density has increased in forested areas.
- Tree density has greatly increased in forested areas.

Figure C.18 Photographic evidence of landscape change in Photo Set #17

(George,C., 2008)

Settlement

- There are no buildings present in either of the photographs.

Transportation Infrastructure

- There are dirt pathways that line both sides of the Yangtze River in the historical photograph. The pathway on the right bank appears right along the river. On the left bank, as well as a pathway running along the river, there is also one on the upper slope.
- In the recent photograph, paved roadways run along the Yangtze River on both banks. Erosion (human-induced) is prominent along the roadways.
- The same dirt pathway that existed in 1923, running along the upper left bank, still exists in 2008.

Industrial/Power Infrastructure

- There is a prominent horizontal line running along the upper slopes of the right riverbank in the recent photograph. This pathway holds a pipeline that I suspect is carrying water from the Snow Mountains to the village.
- Hydro lines run along the pathway on the left riverbank of the recent photograph.

Pasture Lands

- The arid grasslands appearing on the left bank in both photographs seem to be appropriate grazing lands for sheep and goats. During my fieldwork, I saw sheep grazing in this area. Because this vegetation community shows no significant changes between photographs, I hypothesize that there has been continuous grazing in this area throughout the past century. Continuous grazing would hinder the growth of woody plants.

Fluvial

- There is a seasonal island evident in the photograph taken in 1923 at the bottom of the photograph. The local people call it 'the fish belly'. It is evident throughout the dry season. Because the 2008 photograph was taken during the rainy season, the water levers were too high to expose much of the fluvial geomorphology. However, on our first pass of Tiger Leaping Gorge in 2008, the fish belly was still evident.
- The riverbank vegetation has not increased significantly.

Vegetation Communities

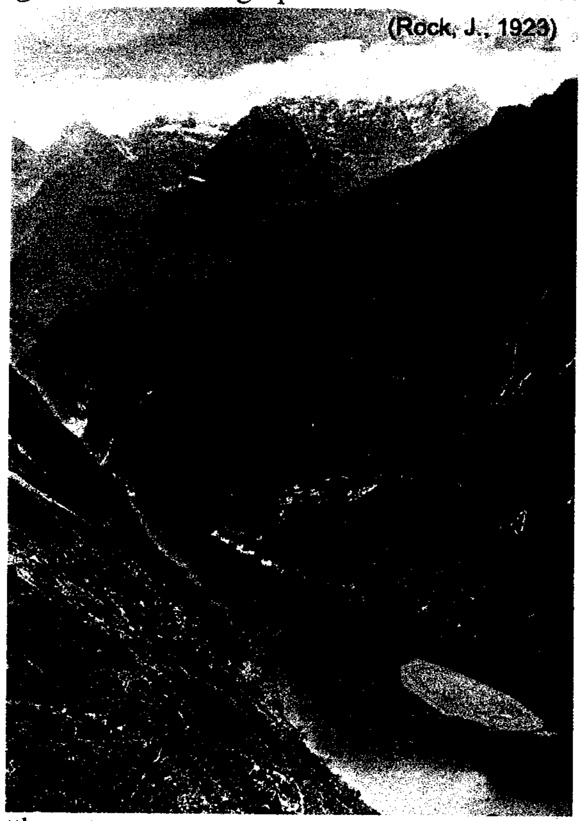
- Arid grassland, arid shrubland, woodland, *Pinus* forest, mixed forest, and subalpine conifer forest are all present in both photographs. The upper treeline appears to be fairly stable; however, mixed forest appears to have ascended.
- Shrubland occurring on the lower right bank in the historical photograph seems to have been replaced with sclerophyllous *Quercus*/bamboo forest.
- Vegetation communities have shifted some, suggesting an increase in temperature and precipitation levels over the past century.

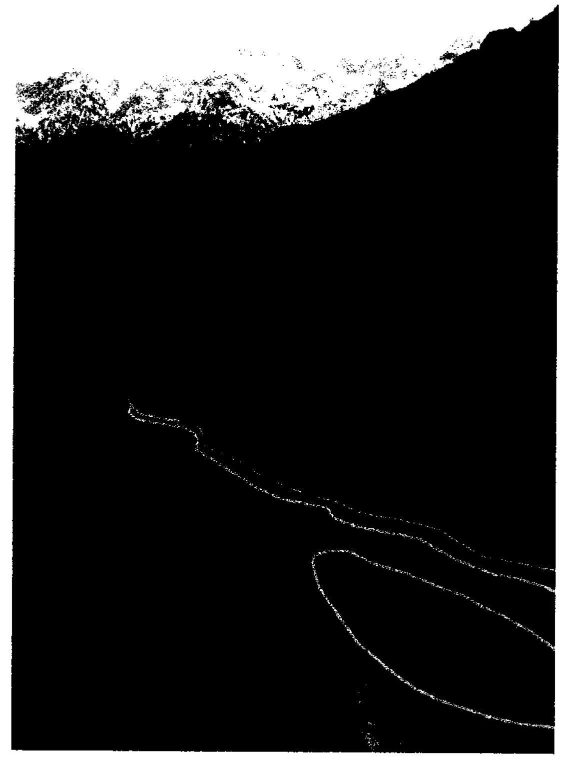
Geomorphology

- Significant mass wasting is taking place in the historical photograph. Wasting seems to have decreased by 2008, but there are several new rock faces exposed.

Figure C.19 Photographic evidence of landscape change in Photo Set #18

(Rock, J., 1923) (Moseley, R., 2003)





Settlement

- There is little settlement present in either photograph. The few houses (3) that were present in the historical photograph have since been taken down.

Transportation Infrastructure

- Dirt pathways are a prominent feature in the historical photograph, running along both banks, as well as at higher altitudes. Paved roadways running along the Yangtze River are present on both banks in the recent photograph. There is also a prominent horizontal line running across the mountain range. This pathway holds a pipeline that I suspect is carrying water.
- Erosion is prominent along the roadways (human-induced) in the newer photograph.

Industrial/Power Infrastructure

- There is no infrastructure of this sort evident in either photograph, other than the pipeline in the recent photograph.

Agricultural Lands

- The little area occupied by agricultural lands in 1923 has since been abandoned and shrubland/woodland has grown in its location.

Pasture Lands

- Although I cannot confirm it, the arid grasslands on the left bank seem like appropriate grazing lands for sheep and goats. This vegetation community shows no significant changes between photographs.

Human-Impacted Vegetation

- There is evidence of deforestation in the lower right corner during the time period between photographs.
- Riverbank vegetation has not changed significantly (shrubland).

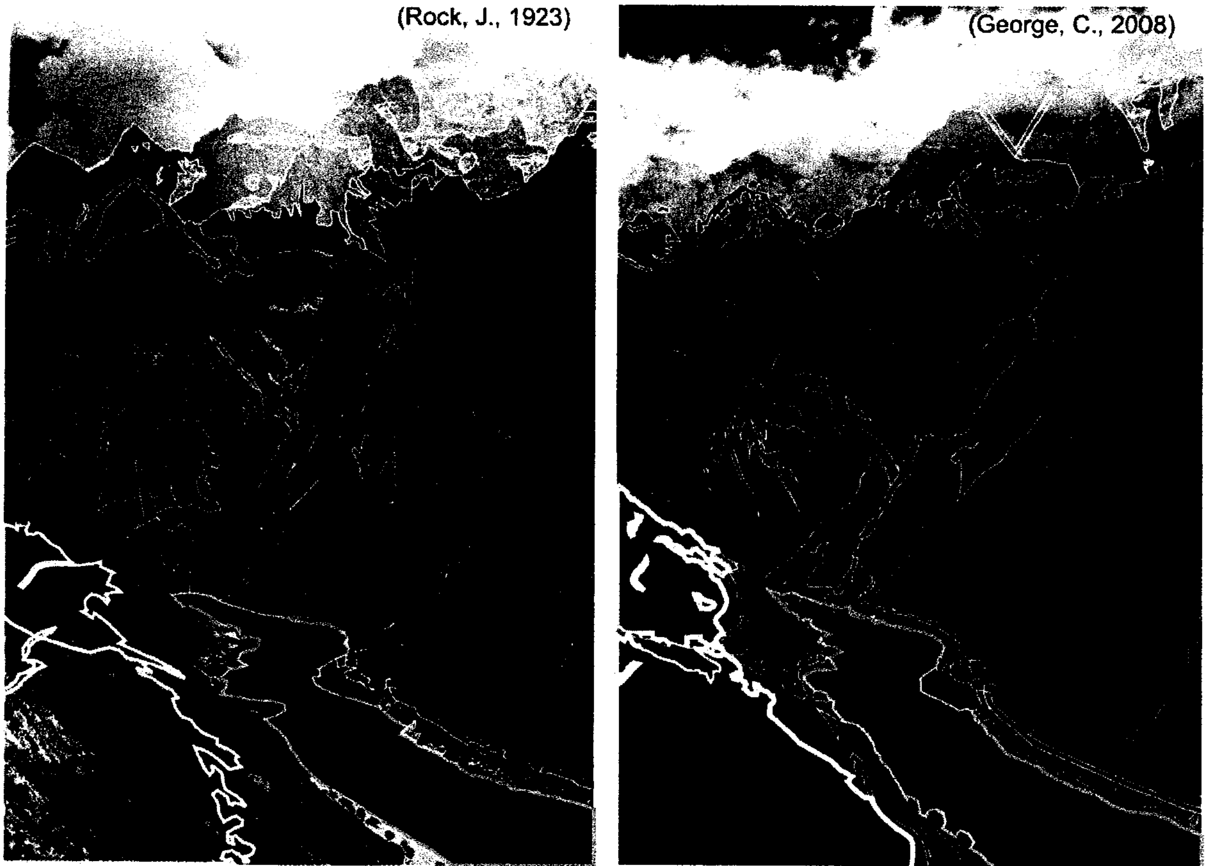
Fluvial

- The water level is low in both photographs, but it is extremely low in the more recent photograph. The evident fluvial geomorphology suggests that there is a drastic seasonal variation in water level.

Vegetation Communities

- Arid grasslands/shrublands, woodlands, *Pinus* forest, mixed forest, and subalpine coniferous forest are all present in both photographs.

Figure C.20 Photographic evidence of landscape change in Photo Set #19



Settlement
- There are buildings present in both photographs. In the historical photograph, there are a few houses standing on the right bank by the river. In the recent photograph, there are buildings in the same location; however, they look to be commercial, as the area has been transformed into a parking lot for tour buses.
- On the left bank, there is evidence of a village, with a few houses that, while present in 2008, are not evident in the historical photograph.

Transportation Infrastructure
- Dirt pathways line both sides of the Yangtze River in the historical photograph. Paved roadways running along the Yangtze River are present on both banks in the more recent photograph. There is also a prominent horizontal line running across the mountain range. This pathway holds a pipeline that I suspect is carrying water.
- Erosion is prominent along the roadways (human-induced) in the newer photograph.

Industrial/Power Infrastructure
- There is no infrastructure of this sort evident in either photograph.

Agricultural Lands
- There are significant agricultural lands located on the left bank in the recent photograph. There is no evidence that they were present in 1923.

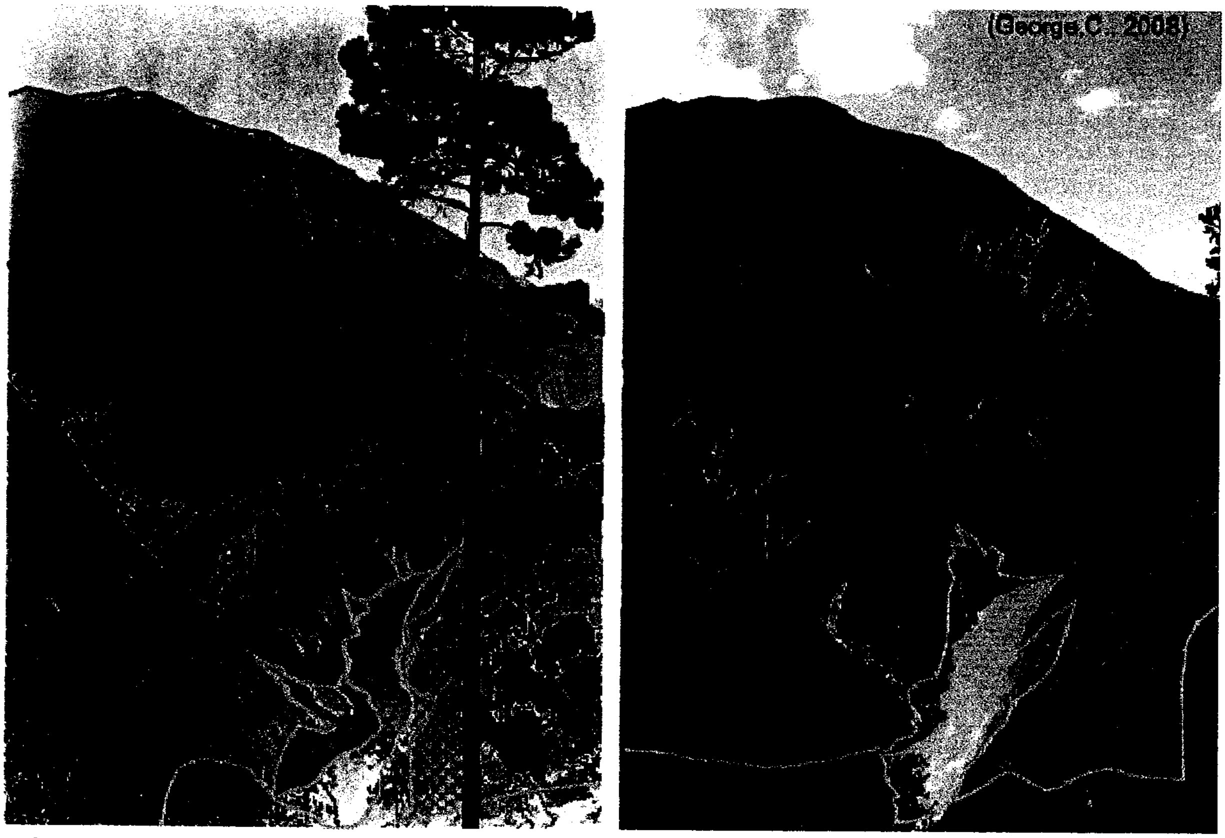
Pasture Lands
- The arid grasslands present on the left bank are appropriate grazing lands for sheep and goats. I saw sheep grazing in this area while I was hiking through Tiger Leaping Gorge. This vegetation community shows no significant changes between photographs.

Fluvial
- The water level is low in both photograph, but it is extremely low in the more recent photograph. The evident fluvial geomorphology suggests that there is a drastic seasonal variation in water level.
- The riverbank vegetation has not changed significantly (shrubland).

Vegetation Communities
- Arid grassland/shrubland, woodland, *Pinus* forest, mixed forest, and subalpine conifer forest are present in both photographs in this photo set. The alpine environment seems relatively stable, but this is extremely difficult to assess using these photographs.

Geomorphology
- Significant mass wasting is taking place in the historical photograph. The wasting seems to have decreased by 2008, but there are several new rock faces exposed in the recent photograph.

Figure C.21 Photographic evidence of landscape change in Photo Set #20



Settlement

- There appears to be a building in each photograph, located on the far riverbank, by the severe mass wasting.

Transportation Infrastructure

- I retook this photograph from the well-known hiking trail on the upper slopes of Tiger Leaping Gorge. I believe that Joseph Rock was travelling along the same trail when he took the original photograph in 1923.
- There are paved roadways running along either side of the Yangtze River. Only the roadway on the opposite bank is visible. A bridge crosses a mass wasting event.

Industrial/Power Infrastructure

- There is no infrastructure of this sort evident in the historical photograph; however, in the recent photograph, there is evidence of a water pipe running horizontally along the high slopes on the other side of the river.

Fluvial

- The water level is higher in the more recent photograph. This represents the seasonal variation in water level. It does not suggest that the water levels on the Yangtze River have increased. Because of the high water level in the more recent photograph, there is less fluvial geomorphology exposed.

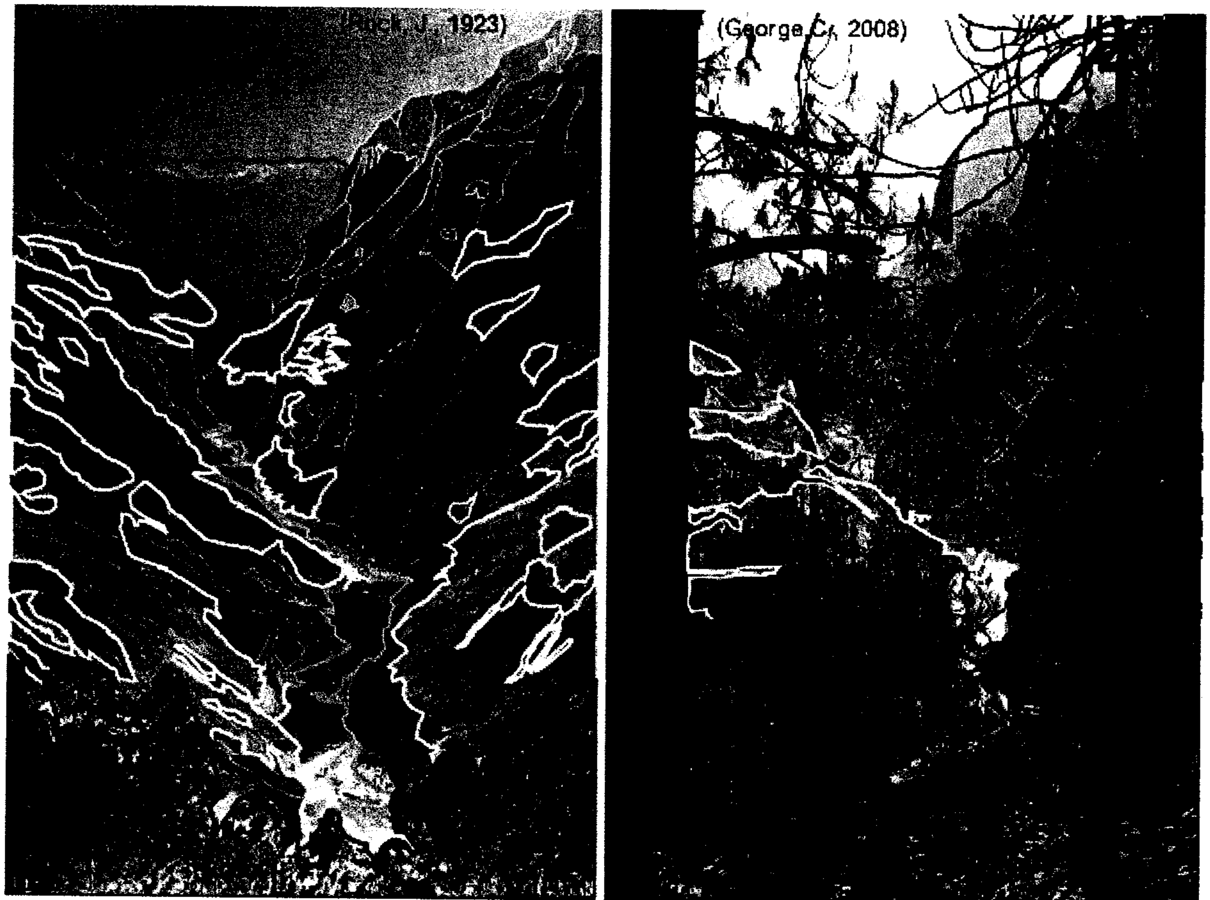
Vegetation Communities

- Vegetation communities do not seem to be greatly impacted by humans in either photograph.
- There is a significant difference between the vegetation communities present on each slope in both photographs. This indicates that aspect is an important driver for determining the distribution of vegetation communities.
- Arid grassland/shrubland and sclerophyllous *Quercus*/bamboo forest are present on the south-facing slopes, while *Quercus*/bamboo forest, mixed forest, and subalpine conifer forest reside on the far side of the river.

Geomorphology

- Significant mass wasting is taking place in the historical photograph. The wasting seems to have decreased by 2008, but there are several new rock faces exposed in the recent photograph.

Figure C.22 Photographic evidence of landscape change in Photo Set #21



Transportation Infrastructure

- There is no transportation infrastructure present in the historical photograph. In the recent photograph, there is a paved roadway running along the left side of the river. Above the roadway is a very pronounced hiking trail and a pipe system carrying water.
- Erosion is prominent along the roadways (human-induced) in the newer photograph.

Fluvial

- Not much of the Yangtze River can be seen in the newer photograph because of the vegetation in the foreground. Despite this, it is evident that the water level is higher in the more recent photograph. This represents the seasonal variation in water level. It does not suggest that the water levels of the Yangtze River have increased. Because of the high water level in the more recent photograph, there is less fluvial geomorphology exposed.

Vegetation Communities

- The vegetation communities do not seem to be greatly impacted by humans in either photograph. Livestock grazing may be occurring on the left l left bank of the Yangtze River, sustaining the grassland that exists.
- Arid grassland/shrubland, woodland, *Pinus* forest, mixed forest, and subalpine conifer forest are present in the photo set.
- The distribution of vegetation communities within the photographed landscape has changed significantly, suggesting an increase in temperature/precipitation in the area.

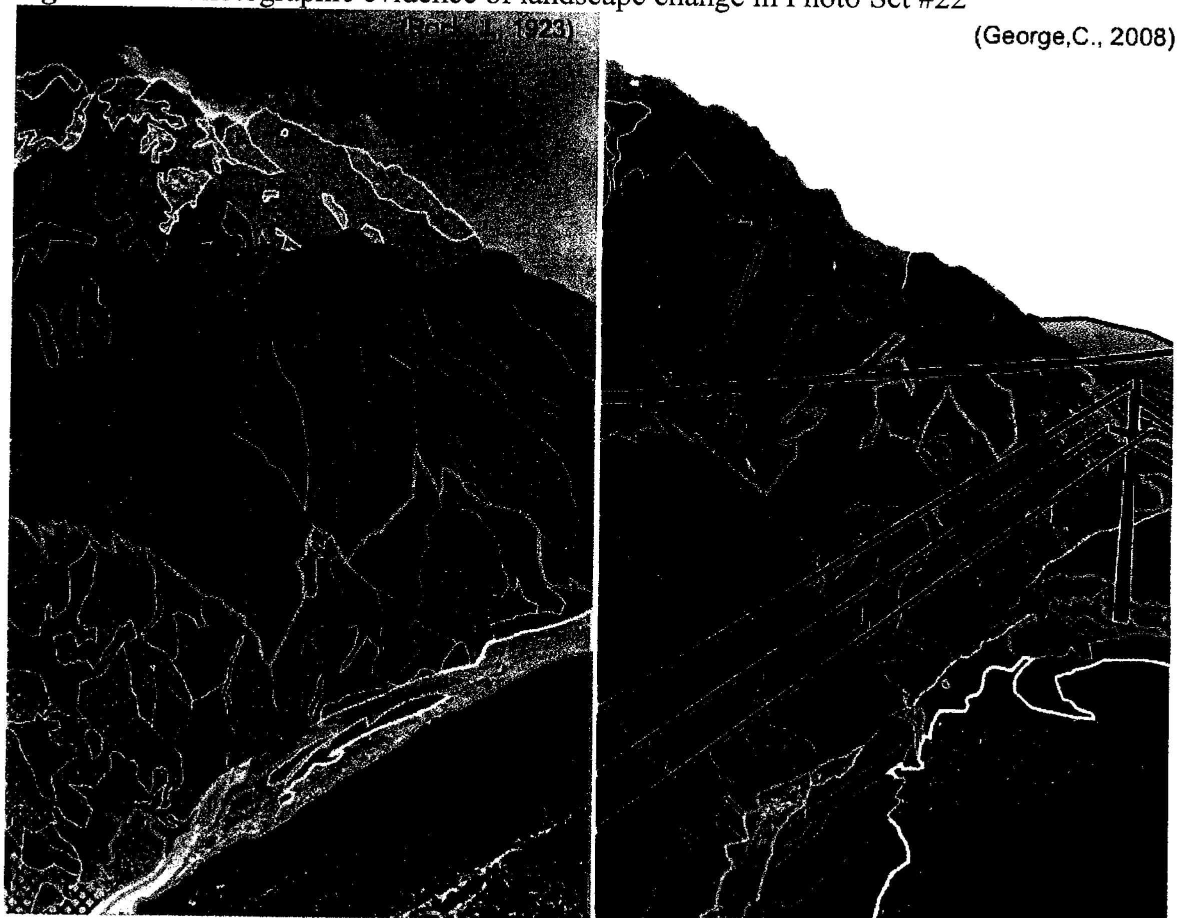
Geomorphology

- Much more geomorphology is exposed in the historic photograph. The level of vegetation has greatly increased over the past century, covering the previously-exposed geomorphology.

Undetermined

- Because of the dense vegetation that is present in the foreground of the recent photograph, it is extremely difficult to determine the vegetation communities and landscape classifications that are present in the background and middle ground. Because of this, it is difficult to assess the overall landscape changes that have occurred.

Figure C.23 Photographic evidence of landscape change in Photo Set #22



Transportation Infrastructure

- There is no transportation infrastructure present in the 1923 photograph. In the photograph taken in 2008, there is a paved roadway running along the right side of the river below the photo point. Above the roadway is a very pronounced hiking trail.

Industrial Infrastructure

- There is no industrial infrastructure present in the historical photograph; however, in the recent photograph, power lines and a hydro pole are evident. The hydro line is running along the hiking trail.

Fluvial

- The water level is higher in the more recent photograph. This represents the seasonal variation in water level. It does not suggest that the water levels of the Yangtze River have increased. Because of the high water level in the more recent photograph, there is less fluvial geomorphology exposed.

Vegetation Communities

- Vegetation communities do not seem to be greatly impacted by humans in either photograph. There is a significant difference between the vegetation communities present on each slope in both photographs. This indicates that aspect is an important driver for determining the distribution of vegetation communities. Arid grasslands, shrublands, and woodlands are present on the south-facing slopes. *Quercus*/bamboo forest, mixed forest, and subalpine conifer forest reside on the far side of the river.
- The distribution of vegetation communities within the photographed landscape has changed significantly, suggesting an increase in temperature/precipitation in the area.

Geomorphology

- The geomorphology exposed in this photo set has stayed about the same over time.

APPENDIX D:
PHOTO ANALYSIS
PRESENCE/ABSENCE AND DEGREES OF CHANGE

This appendix offers the reader the results of the qualitative photo interpretation that was conducted on the photo sets containing a photograph taken in 2008. This analysis was conducted using methodology recommended by Zier and Baker (2006) and includes presence/absence, a measurement of stability and an indication of the degrees of change. Each landscape classification is marked as present (P) or absent (A), and stability is indicated as increasing, decreasing or stable. Finally, the degrees of change are indicated as slight, moderate, and extensive. Each landscape classification is coloured according to the legend below.

Figure D.1 The legend for the colour-coded landscape classifications.

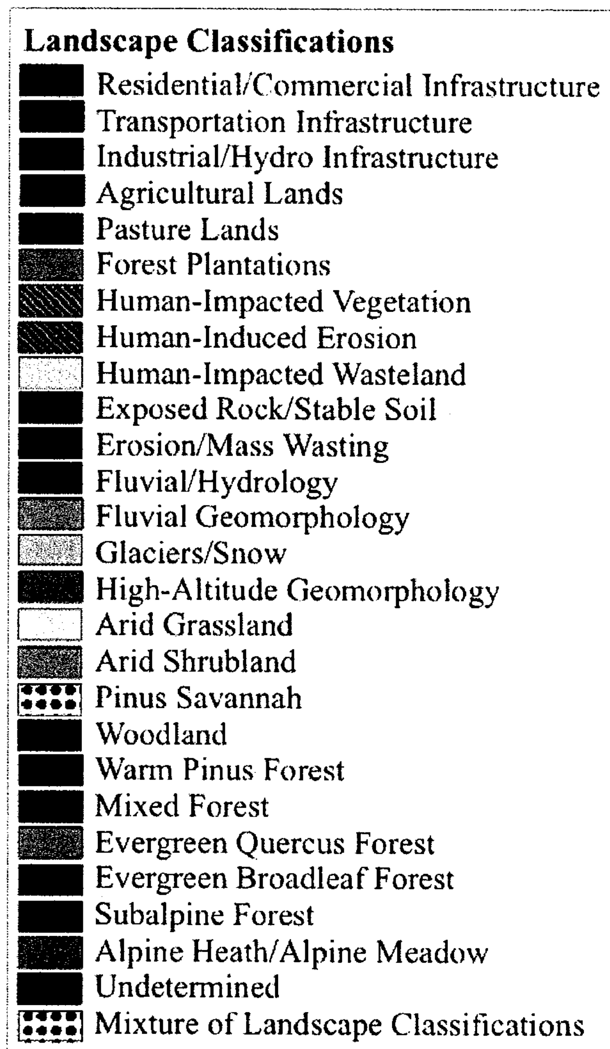
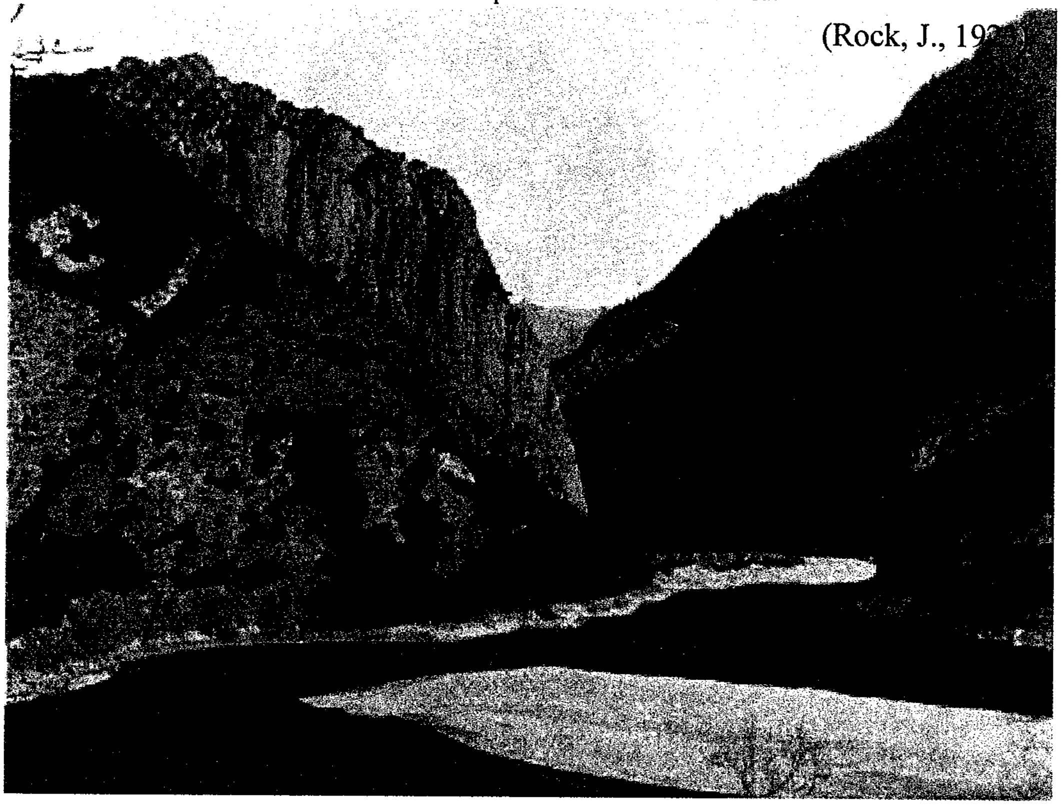
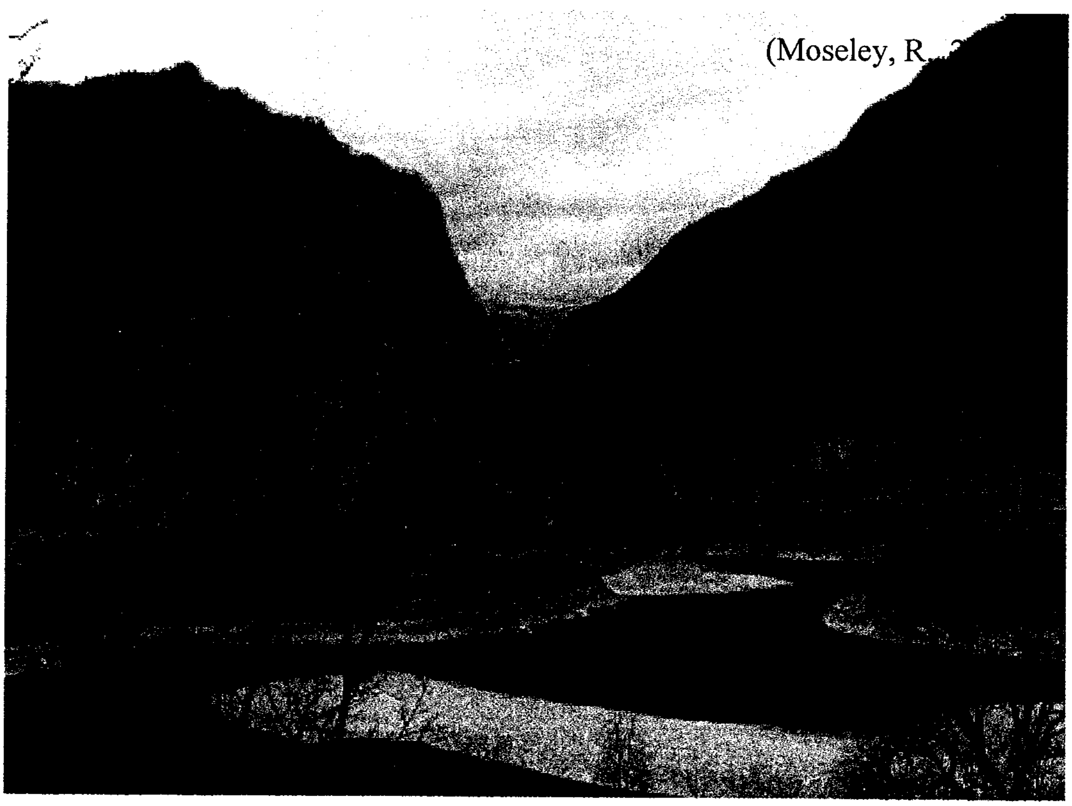


Photo Set #1

Figure D.2 Photo Set #1 with colour-coded landscape classifications overlaid.





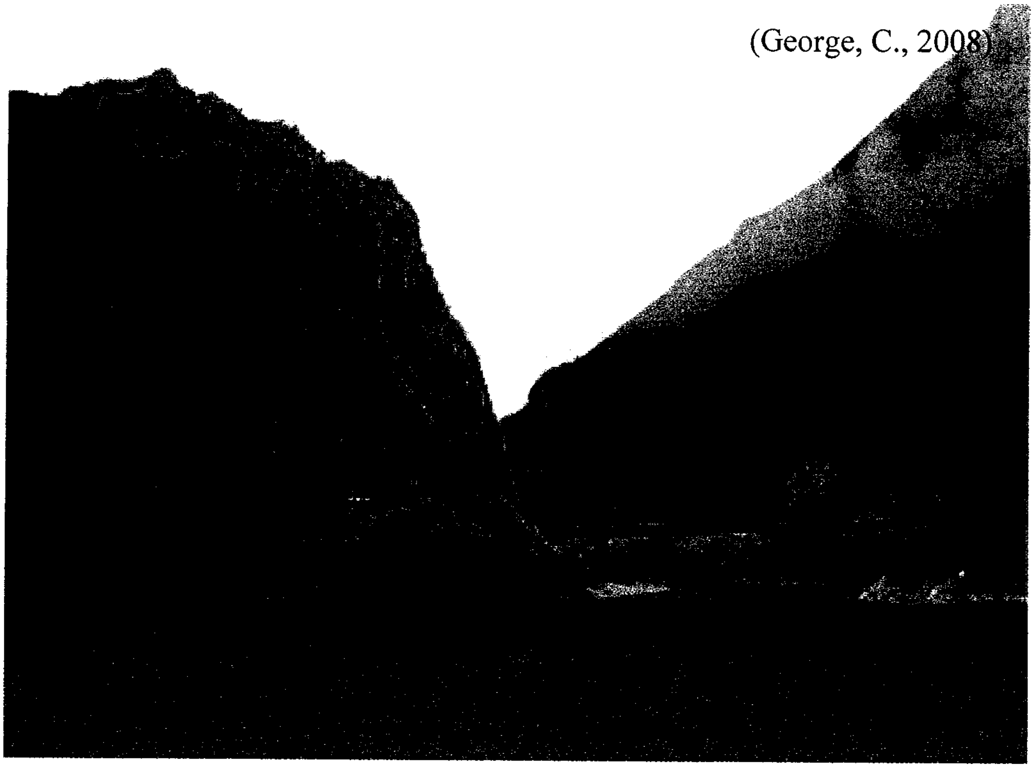

(George, C., 2008)

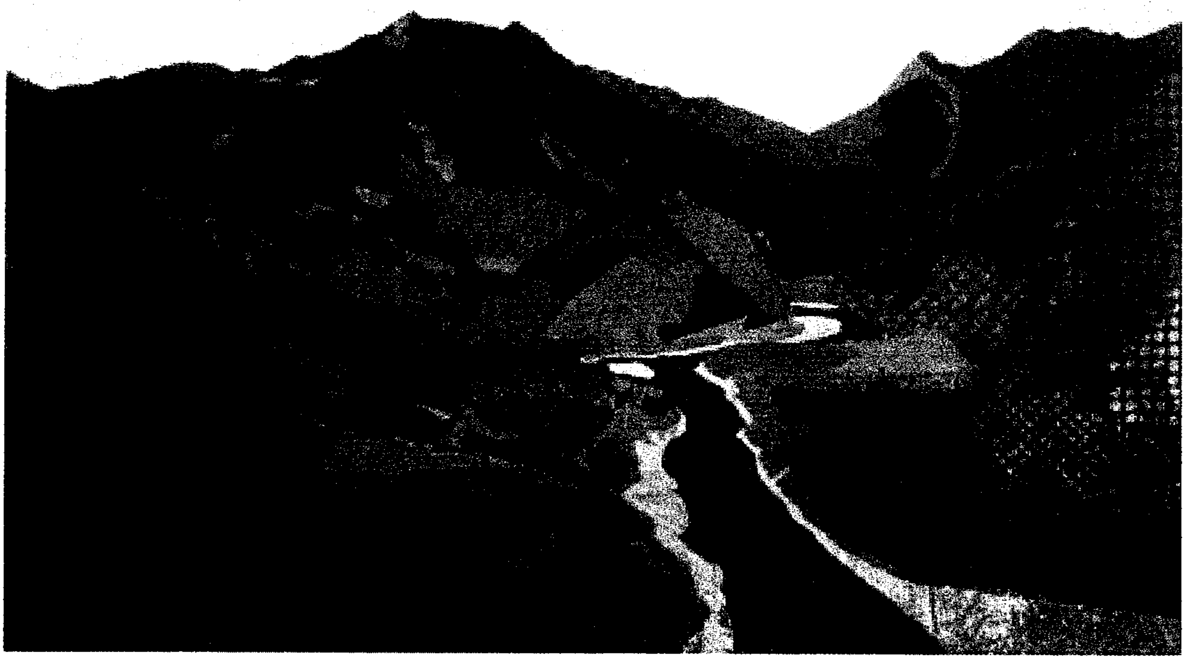
Table D.1 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #1

Photo Set # 1 Landscape Characteristics	Presence/Absence Rock (1923)	Moseley (2003)	George (2008)	Trend	Degrees of Change
Settlement	A	P	P	Increasing	Slight
Transportation Infrastructure	A	P	P	Increasing	Moderate
Industrial Infrastructure	A	P	P	Increasing	Moderate
Agricultural Lands	P	P	P	Stable	N/A
Grazing Lands	A	A	A	Stable	N/A
Forest Plantation	A	A	A	Stable	N/A
Human-impacted Vegetation	A	P	P	Increasing	Moderate
Human-impacted Erosion	A	P	P	Increasing	Moderate
Human-impacted Wasteland	A	P	P	Increasing	Moderate
Rock	P	P	P	Decreasing	Slight
Mass Wasting/Erosion	P	P	P	Decreasing	Slight
Glacier/Snow	A	A	A	Stable	N/A
Fluvial	P	P	P	Increasing	Slight
Glacial Geomorphology	P	P	P	Decreasing	Slight
Arid Grassland	A	A	A	Stable	N/A
Arid Shrubland	P	P	P	Stable	N/A
Woodlands	P	P	A	Decreasing	Extensive
Warm *Pinus* Forest	P	P	P	Increasing	Extensive
Mixed Forest	A	A	A	Stable	N/A
Evergreen *Quercus* Forest	A	A	A	Stable	N/A
Evergreen Broadleaf Forest	A	A	A	Stable	N/A
Subalpine Forest	A	A	A	Stable	N/A
Subalpine Meadow	A	A	A	Stable	N/A
Alpine Heath	A	A	A	Stable	N/A
Alpine Meadow	A	A	A	Stable	N/A

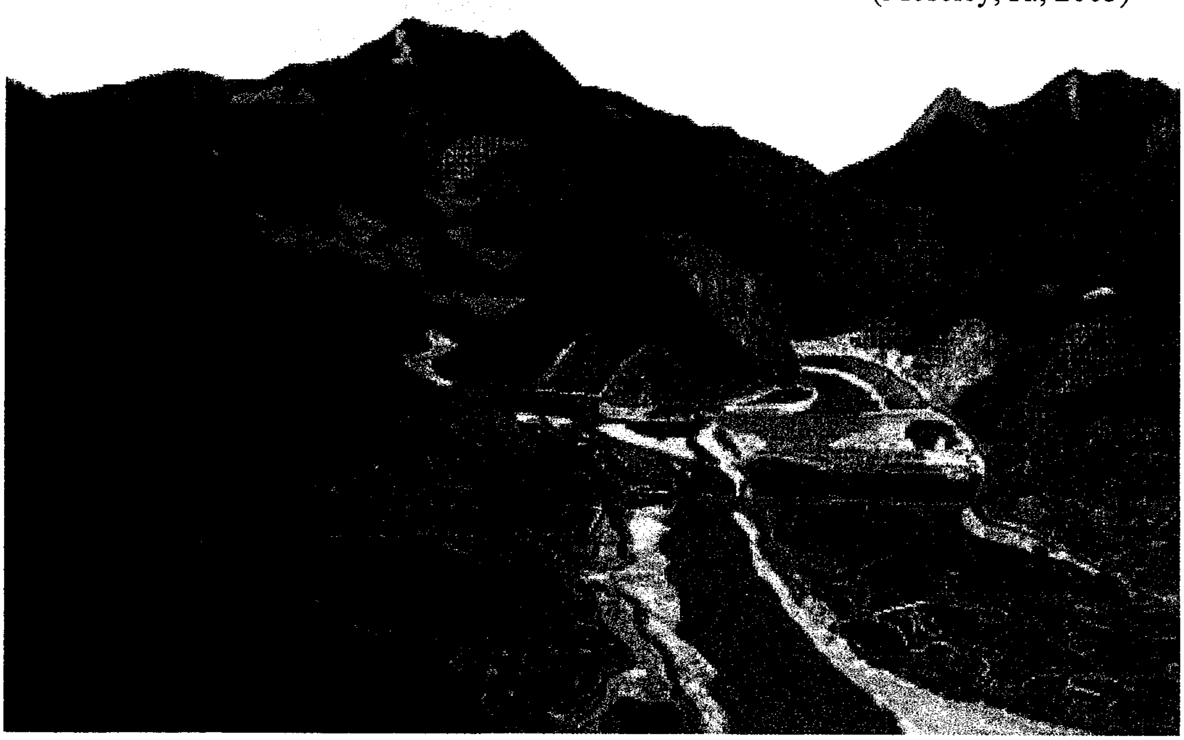
Photo Set #3

Figure D.3 Photo Set #3 with colour-coded landscape classifications overlaid.

(Rock, J., 1923)



(Moseley, R., 2003)



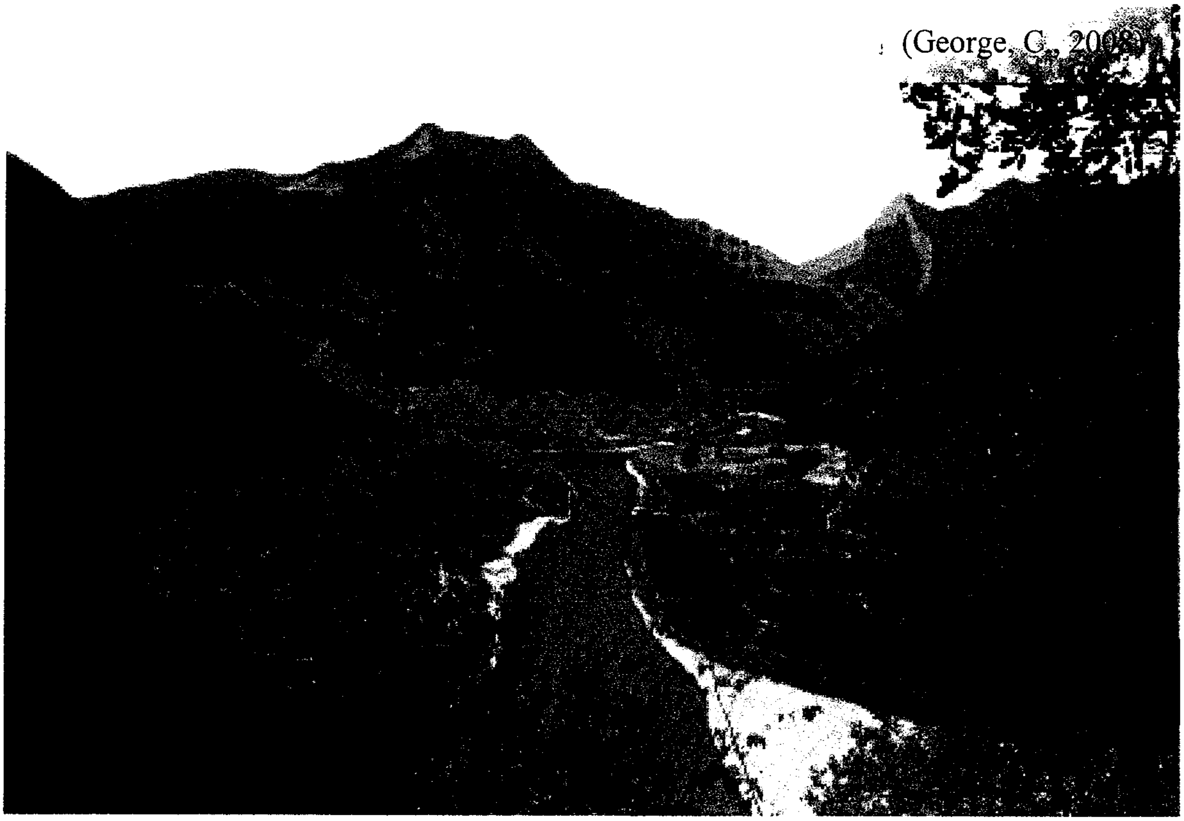

(George, C., 2008)

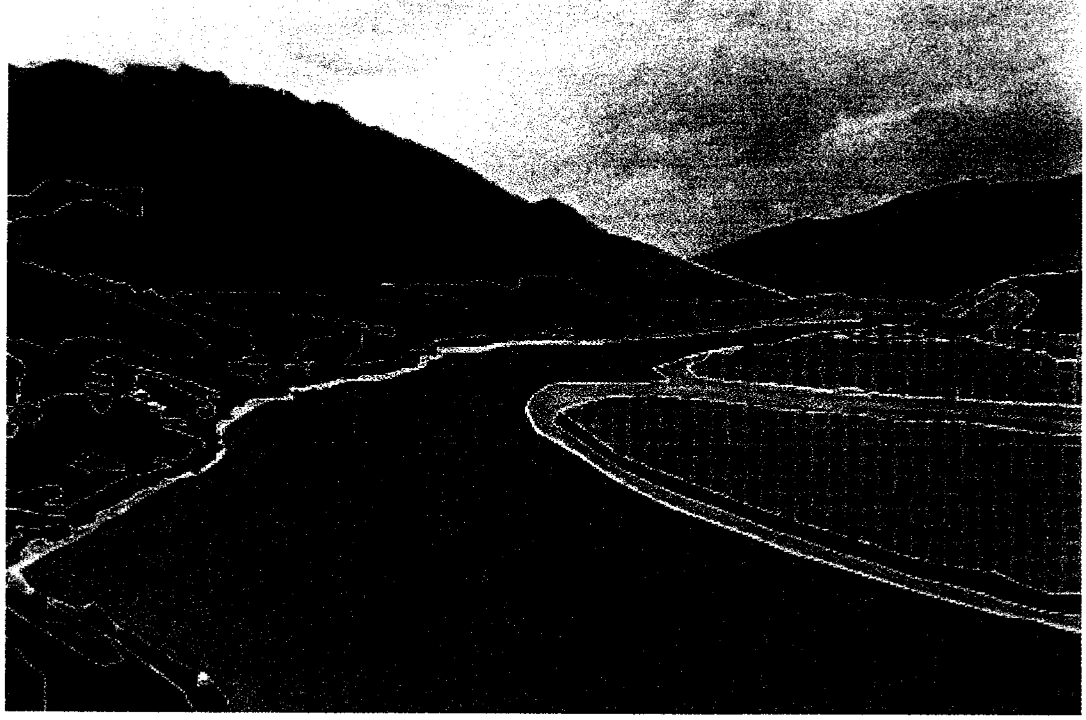
Table D.2 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #3

Photo Set # 3 Landscape Characteristics	Presence/Absence Rock (1923)	Moseley (2003)	George (2008)	Trend	Degrees of Change
Settlement	P	P	P	Increasing	Moderate
Transportation Infrastructure	A	P	P	Increasing	Moderate
Industrial Infrastructure	A	P	P	Increasing	Moderate
Agricultural Lands	P	P	P	Decreasing	Extensive
Grazing Lands	P	P	P	Decreasing	Slight
Forest Plantations	A	A	A	Stable	N/A
Human-Impacted Vegetation	P	P	P	Increasing	Extensive
Human-Impacted Erosion	A	P	P	Increasing	Moderate
Human-Impacted Wasteland	P	P	P	Increasing	Slight
Rock	P	P	P	Stable	N/A
Mass Wasting/Erosion	P	P	P	Stable	N/A
Glacier/Snow	A	A	A	Stable	N/A
Fluvial	P	P	P	Increasing	Slight
Fluvial Geomorphology	P	P	P	Increasing	Slight
High Altitude Geomorphology	A	A	A	Stable	N/A
Arid Grassland	P	A	A	Decreasing	Slight
Arid Shrubland	P	P	P	Stable	N/A
Woodlands	P	P	A	Decreasing	Extensive
Warm *Pinus* Forest	P	P	P	Decreasing	Slight
Mixed Forest	P	P	P	Increasing	Moderate
Evergreen *Quercus* Forest	A	A	A	Stable	N/A
Evergreen Broadleaf Forest	A	A	A	Stable	N/A
Subalpine Forest	A	A	A	Stable	N/A
Subalpine Meadow	A	A	A	Stable	N/A
Alpine Heath	A	A	A	Stable	N/A
Alpine Meadow	A	A	A	Stable	N/A

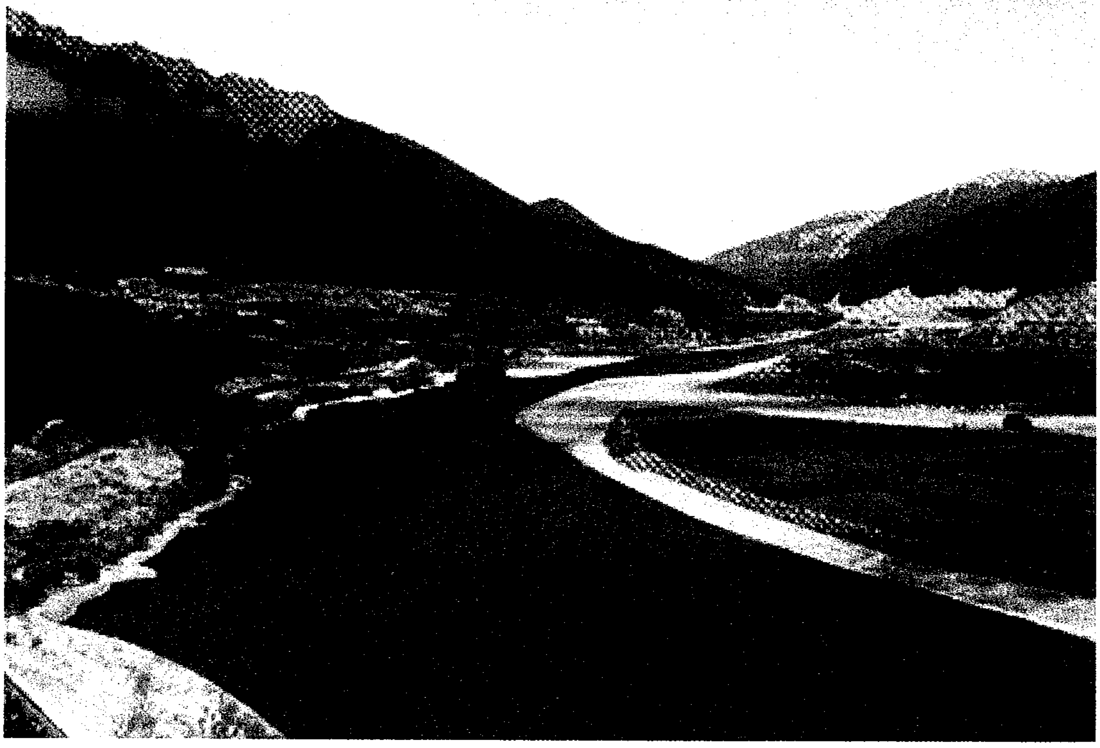
Photo Set #8

Figure D.4 Photo Set #8 with colour-coded landscape classifications overlaid.

(Rock, J., 1923)



(Moseley, R., 2003)



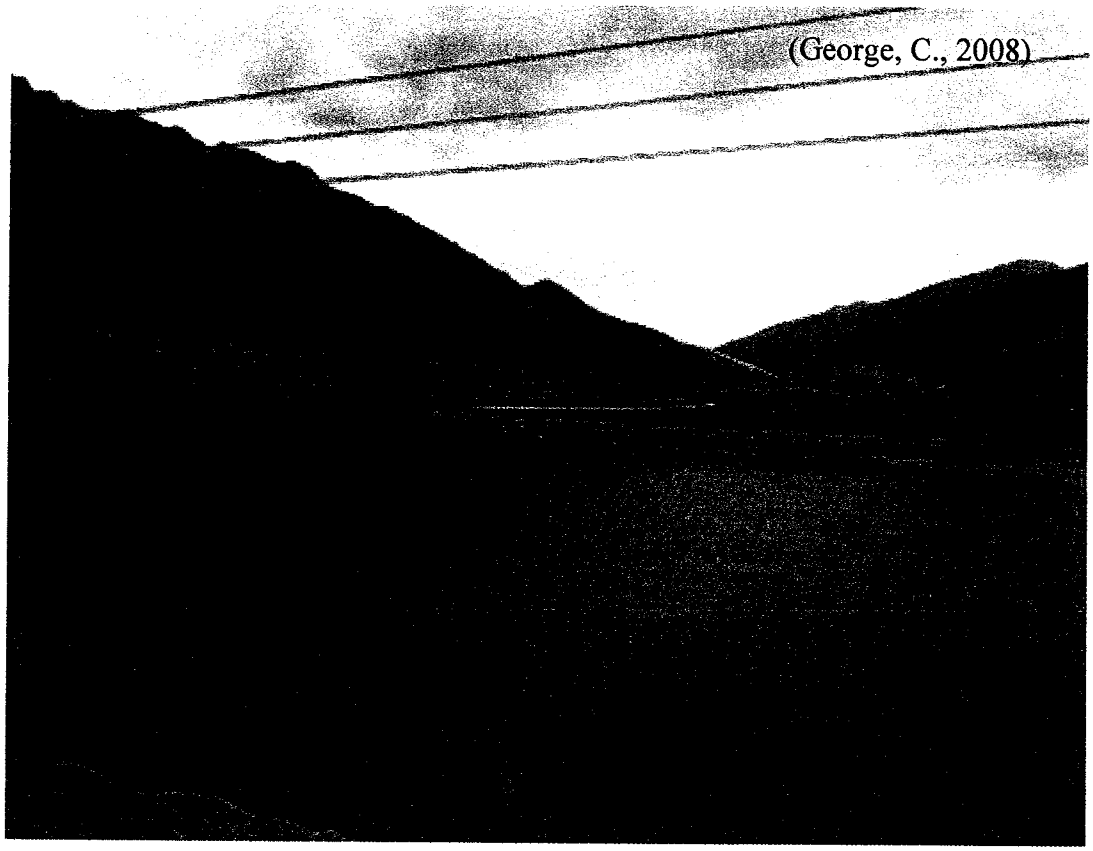
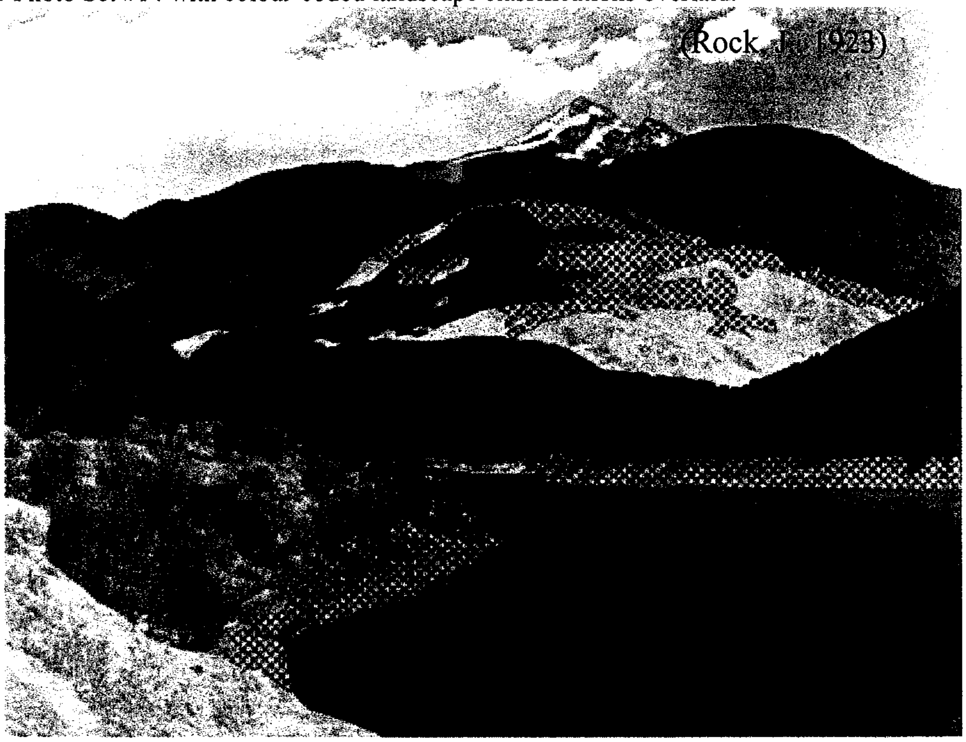

(George, C., 2008)

Table D.3 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #8

Photo Set # 8 Landscape Characteristics	Presence/Absence Rock (1923)	Moseley (2003)	George (2008)	Trend	Degrees of Change
[illegible]					
Settlement	A	P	P	Increasing	Slight
Transportation Infrastructure	A	P	P	Increasing	Moderate
Industrial Infrastructure	A	P	P	Increasing	Moderate
Agricultural Lands	P	P	P	Increasing	Slight
Grazing Lands	A	A	A	Stable	N/A
Forest Plantations	A	A	A	Stable	N/A
Human Impacted Vegetation	P	P	P	Increasing	Slight
Human Impacted Erosion	A	P	P	Increasing	Moderate
Human Impacted Wetland	P	P	P	Decreasing	Moderate
[illegible]					
[illegible]	P	P	A	Decreasing	Slight
Mass Wasting Erosion	P	P	P	Stable	N/A
Glacier/Snow	A	P	A	Stable	N/A
Fluvial	P	P	P	Stable	N/A
[illegible]	P	P	P	Stable	N/A
High Altitude Geomorphology	A	A	A	Stable	N/A
[illegible]					
Arid Steppe	P	A	A	Decreasing	Slight
Arid Shrubland	P	A	A	Decreasing	Extensive
Woodlands	A	P	P	Increasing	Slight
Warm Pine Forest	P	P	P	Stable	N/A
Mixed Forest	P	A	A	Decreasing	Slight
Evergreen Quercus Forest	A	A	A	Stable	N/A
Evergreen Broadleaf Forest	A	A	A	Stable	N/A
Subalpine Forest	A	A	A	Stable	N/A
Subalpine Meadow	A	A	A	Stable	N/A
Alpine Heath	A	A	A	Stable	N/A
Alpine Meadow	A	A	A	Stable	N/A

Photo Set #14

Figure D.5 Photo Set #14 with colour-coded landscape classifications overlaid.



(George, C., 2008)

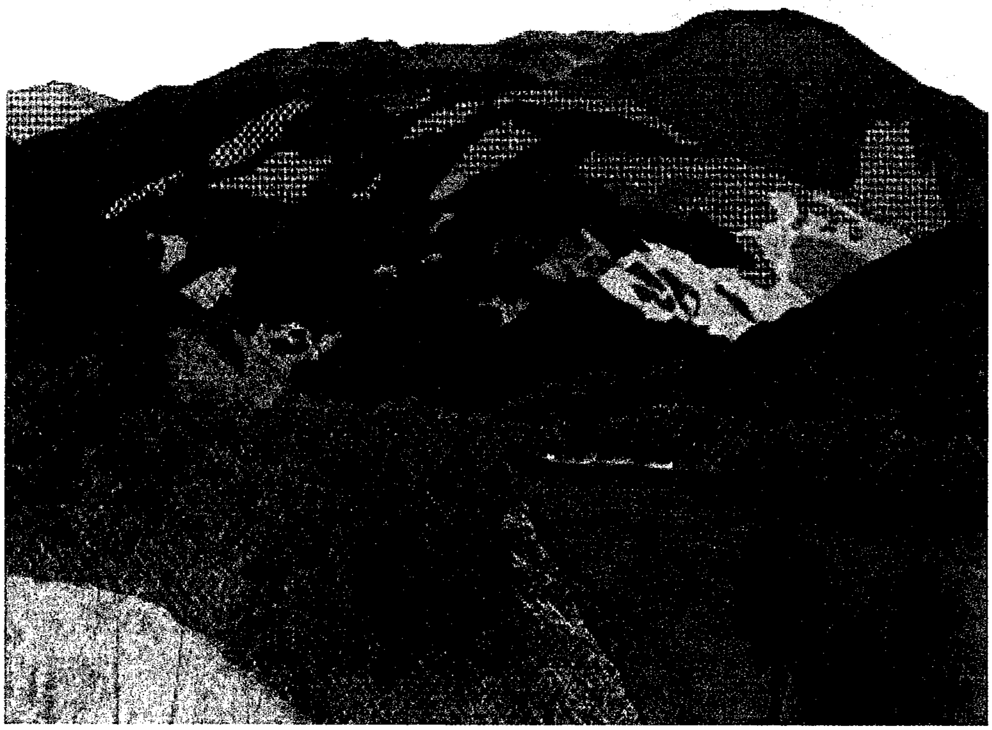


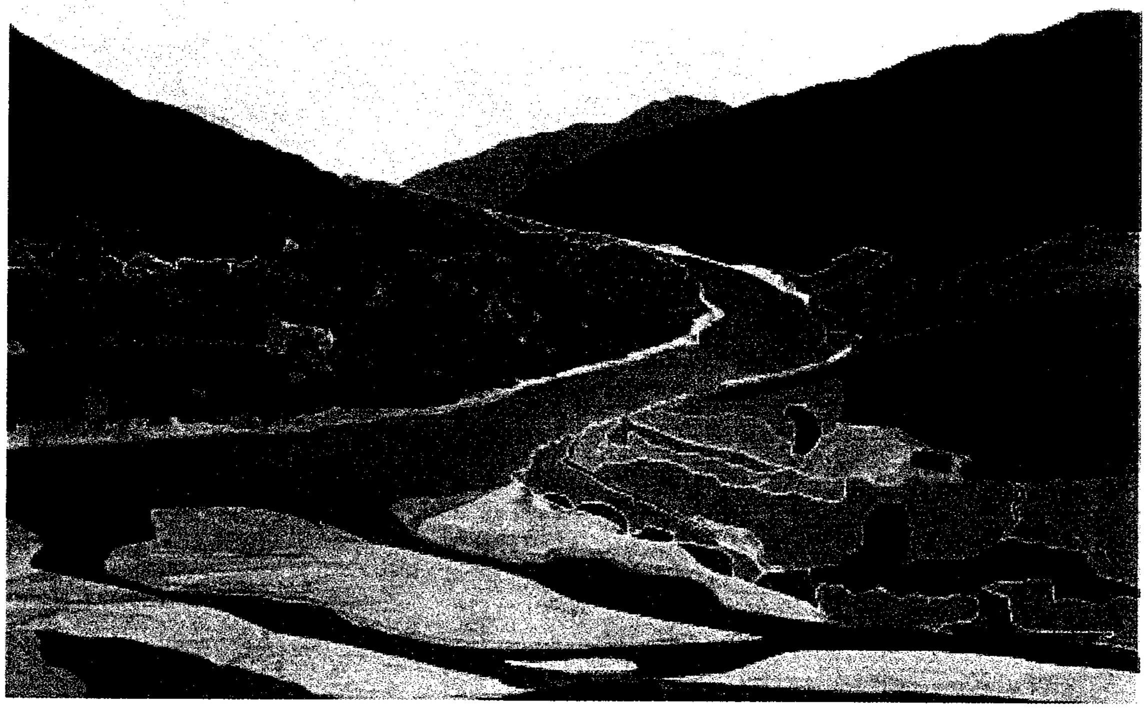
Table D.4 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #14

Photo Set # 14 Landscape Characteristics	Presence/Absence Rock (1923)	Moseley (2003)	George (2008)	Trend	Degrees of Change
Settlement	P	P	P	Increasing	Slight
Transportation Infrastructure	P	P	P	Increasing	Moderate
Industrial Infrastructure	A	P	P	Increasing	Moderate
Agricultural Lands	P	P	P	Decreasing	Moderate
Grazing Lands	A	A	A	Stable	N/A
Forest Plantations	A	A	A	Stable	N/A
Human Impacted Vegetation	A	P	P	Increasing	Extensive
Human Impacted Erosion	A	A	A	Stable	N/A
Human Impacted Wasteland	A	A	A	Stable	N/A
Rock	P	P	P	Increasing	Slight
Mass Wasting/Erosion	P	A	A	Decreasing	Slight
Glacier/Snow	P	A	A	Decreasing	Slight
Fluvial	P	P	P	Increasing	Slight
Fluvial Geomorphology	P	P	P	Decreasing	Moderate
High Altitude Geomorphology	P	P	A	Stable	N/A
Arid Grassland	P	P	P	Decreasing	Slight
Arid Shrubland	P	P	P	Decreasing	Extensive
Arid Savannah	P	P	P	Decreasing	Slight
Woodlands	P	P	P	Increasing	Moderate
Warm Zone Forest	P	P	P	Increasing	Slight
Mixed Forest	P	P	P	Stable	N/A
Evergreen *Quercus* Forest	A	A	A	Stable	N/A
Evergreen Broadleaf Forest	A	A	A	Stable	N/A
Subalpine Forest	P	P	P	Increasing	Slight
Subalpine Meadow	P	P	P	Stable	N/A
Alpine Heath	P	P	P	Stable	N/A
Alpine Meadow	P	P	P	Stable	N/A

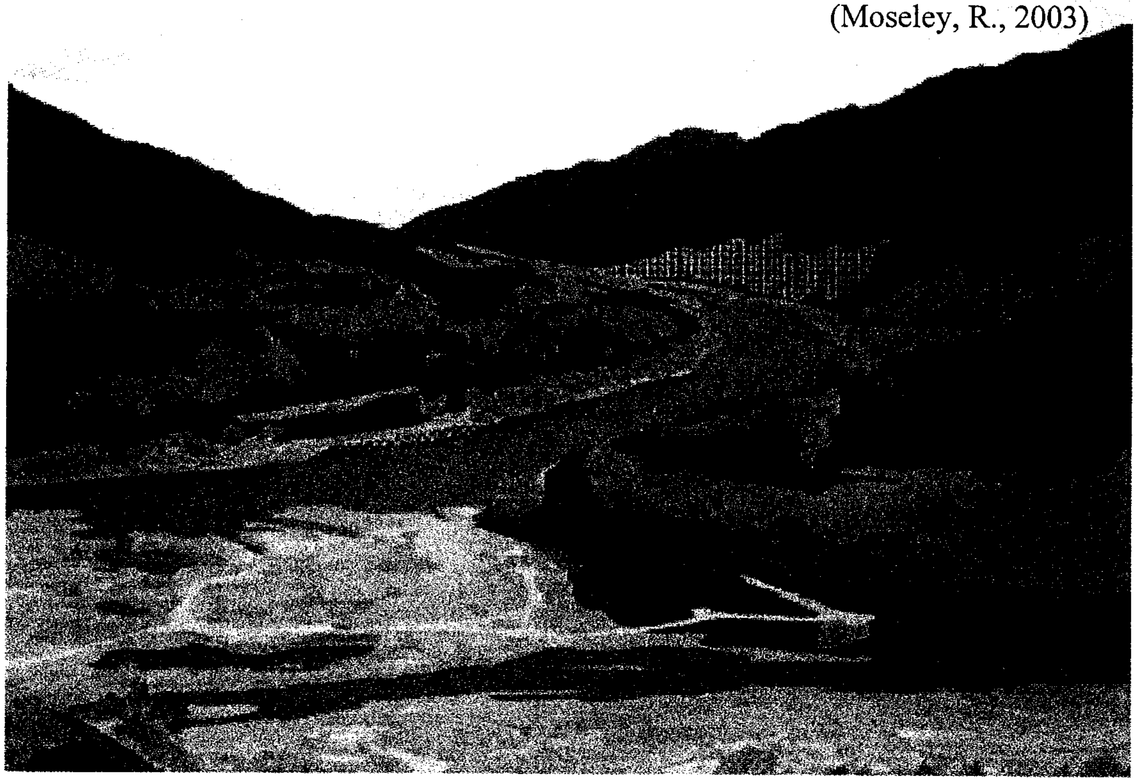
Photo Set #16

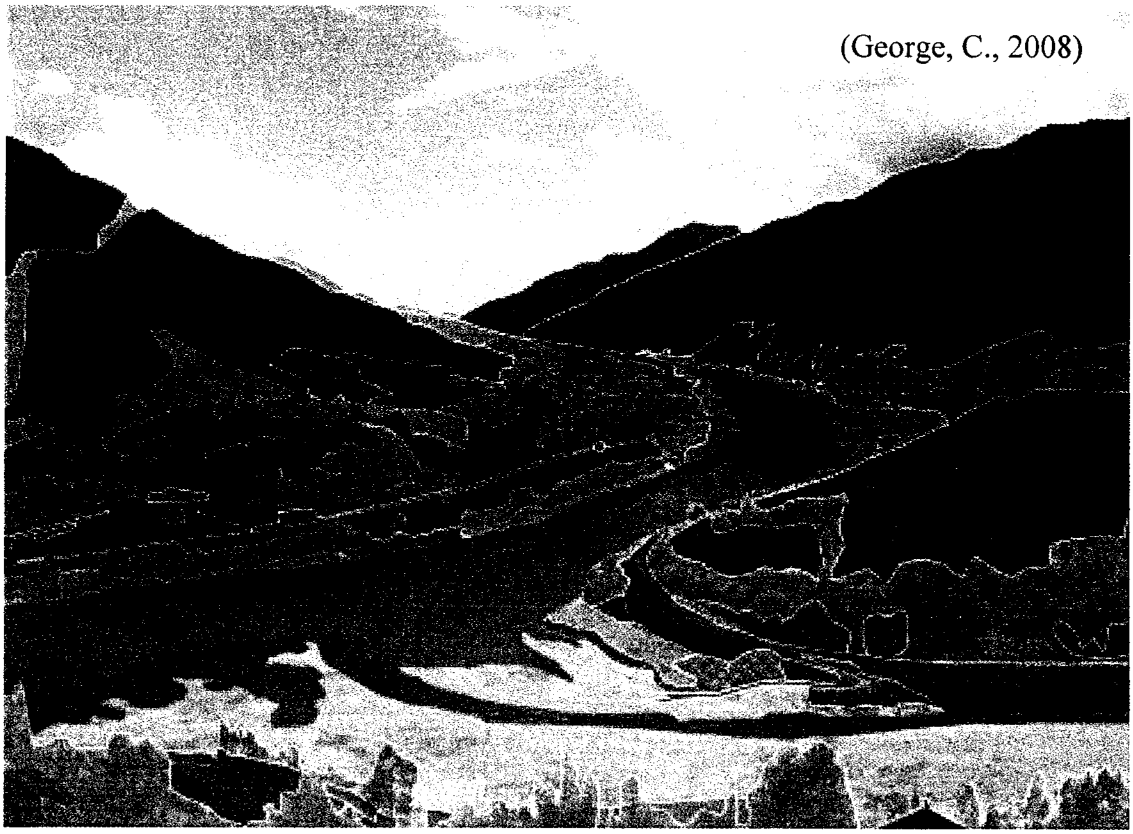
Figure D.6 Photo Set #16 with colour-coded landscape classifications overlaid.

(Rock, J., 1923)



(Moseley, R., 2003)





(George, C., 2008)

Table D.5 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #16

Photo Set # 16 Landscape Characteristics	Presence/Absence Rock (1923)	Moseley (2003)	George (2008)	Trend	Degrees of Change
Settlement	P	P	P	Increasing	Moderate
Transportation Infrastructure	P	P	P	Increasing	Extensive
Industrial Infrastructure	A	P	P	Increasing	Slight
Agricultural Lands	P	P	P	Decreasing	Moderate
Grazing Lands	P	A	A	Decreasing	Slight
Forest Plantations	P	P	P	Increasing	Moderate
Human Impacted Vegetation	A	P	P	Increasing	Moderate
Human Impacted Erosion	P	A	P	Stable	N/A
Human Impacted Wasteland	P	P	P	Decreasing	Slight
Rock	P	P	P	Increasing	Moderate
Mass Wasting/Erosion	P	A	A	Decreasing	Moderate
Glacier/Snow	A	A	A	Stable	N/A
Water	P	P	P	Increasing	Slight
Fluvial Geomorphology	P	P	P	Stable	N/A
High Altitude Geomorphology	A	A	A	Stable	N/A
Arid Grassland	A	P	P	Increasing	Slight
Arid Shrubland	A	P	P	Increasing	Slight
Arid Savanna	A	P	P	Increasing	Slight
Woodlands	P	A	A	Decreasing	Slight
Warm Mixed Forest	P	P	P	Increasing	Slight
Mixed Forest	A	A	A	Stable	N/A
Evergreen [illegible] Forest	A	A	A	Stable	N/A
Evergreen Broadleaf Forest	A	A	A	Stable	N/A
Subalpine Forest	A	A	A	Stable	N/A
Subalpine Meadow	A	A	A	Stable	N/A
Alpine Heath	A	A	A	Stable	N/A
Alpine Meadow	A	A	A	Stable	N/A

Photo Set #17

Figure D.7 Photo Set #17 with colour-coded landscape classifications overlaid.

(George, C., 2008)

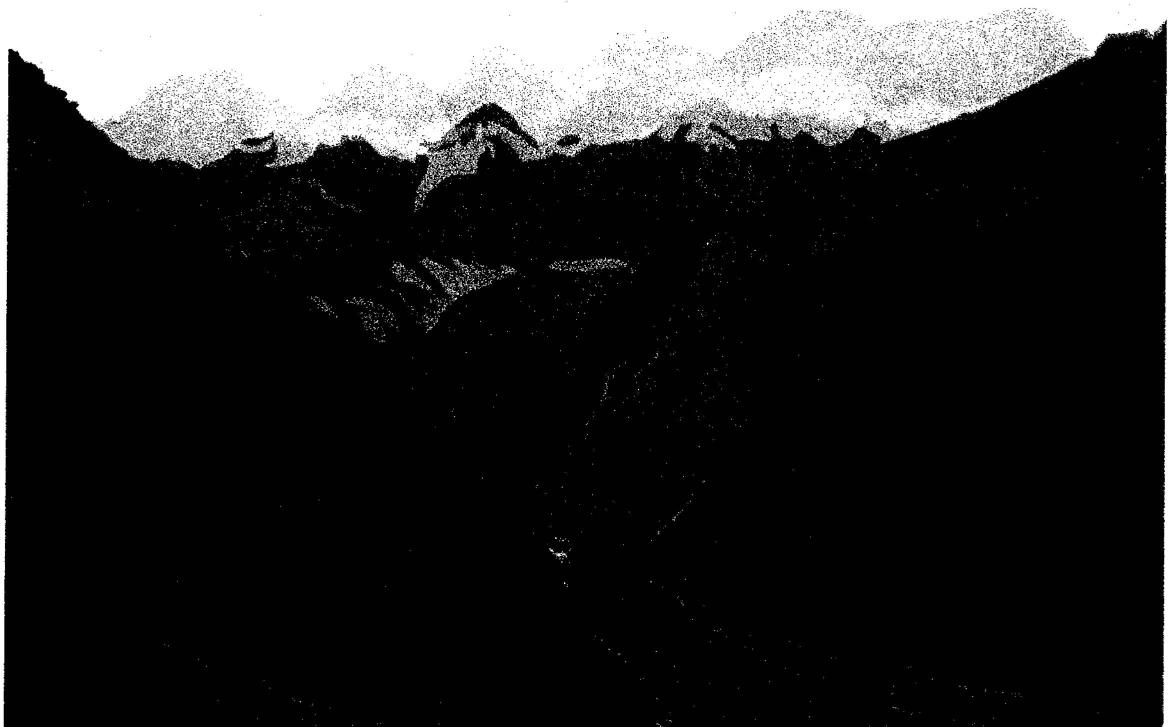


Table D.6 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #17

Photo Set # 17 Landscape Characteristics	Presence/Absence Rock (1923)	George (2008)	Trend	Degrees of Change
Settlement	A	P	Increasing	Slight
Transportation Infrastructure	P	P	Increasing	Moderate
Industrial Infrastructure	A	P	Increasing	Slight
Agricultural Lands	P	A	Decreasing	Moderate
Grazing Lands	P	P	Stable	N/A
Forest Plantations	A	A	Stable	N/A
Human Impacted Vegetation	A	P	Increasing	Moderate
Human Impacted Erosion	A	A	Stable	N/A
Human Impacted Wasteland	A	A	Stable	N/A
Rock	P	P	Increasing	Extensive
Mass Wasting Erosion	P	P	Decreasing	Extensive
Glaciers/Snow	P	P	Decreasing	Slight
Fluvial	P	P	Increasing	Slight
Fluvial Geomorphology	P	P	Decreasing	Moderate
High Altitude Geomorphology	P	P	Increasing	Slight
Arid Grassland	P	P	Decreasing	Slight
Arid Shrubland	P	P	Decreasing	Extensive
Pinus Shrubland	A	A	Stable	N/A
Wetlands	P	P	Increasing	Moderate
Warm *Pinus* Forest	P	P	Decreasing	Extensive
Mixed Forest	P	P	Increasing	Extensive
Evergreen *Quercus* Forest	A	P	Increasing	Slight
Evergreen Broadleaf Forest	A	A	Stable	N/A
Subalpine Forest	P	P	Increasing	Slight
Alpine Meadow	A	A	Stable	N/A

Photo Set #19

Figure D.8 Photo Set #19 with colour-coded landscape classifications overlaid.

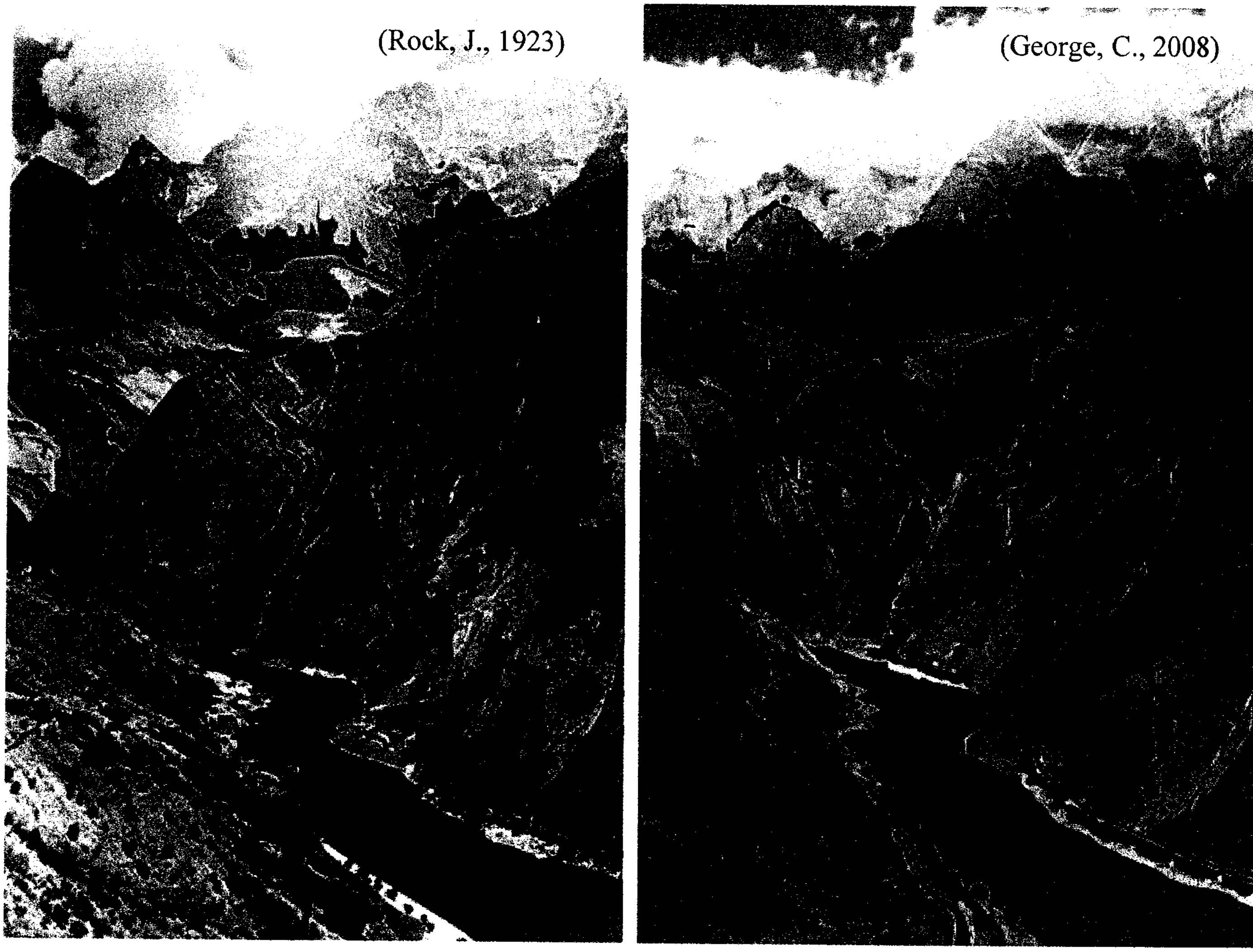


Table D.7 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #19

Photo Set # 19 Landscape Characteristics	Presence/Absence Rock (1923)	George (2008)	Trend	Degrees of Change
[illegible]				
Settlement	P	P	Increasing	Moderate
Transportation Infrastructure	P	P	Increasing	Extensive
Industrial Infrastructure	A	P	Increasing	Moderate
Agricultural Lands	A	P	Increasing	Moderate
Grazing Lands	P	P	Stable	N/A
Forest Plantations	A	A	Stable	N/A
Human-impacted Vegetation	P	P	Increasing	Moderate
Human-impacted Erosion	A	P	Increasing	Extensive
[illegible]				
Rock	P	P	Increasing	Extensive
Mass Wasting/Erosion	P	P	Decreasing	Extensive
Glaciers/Snow	P	P	Decreasing	Moderate
[illegible]	P	P	Increasing	Slight
Fluvial Geomorphology	P	P	Stable	N/A
High Altitude Geomorphology	P	P	Stable	N/A
[illegible]				
Arid Grassland	P	P	Increasing	Moderate
Arid Shrubland	P	P	Decreasing	Extensive
Pinus Savannah	P	P	Decreasing	Extensive
Woodlands	P	P	Decreasing	Moderate
Warm *Pinus* Forest	P	P	Decreasing	Extensive
Mixed Forests	P	P	Increasing	Extensive
Subalpine Forest	P	P	Decreasing	Slight
Subalpine Meadow	P	A	Decreasing	Slight

Photo Set #20

Figure D.9 Photo Set #20 with colour-coded landscape classifications overlaid.

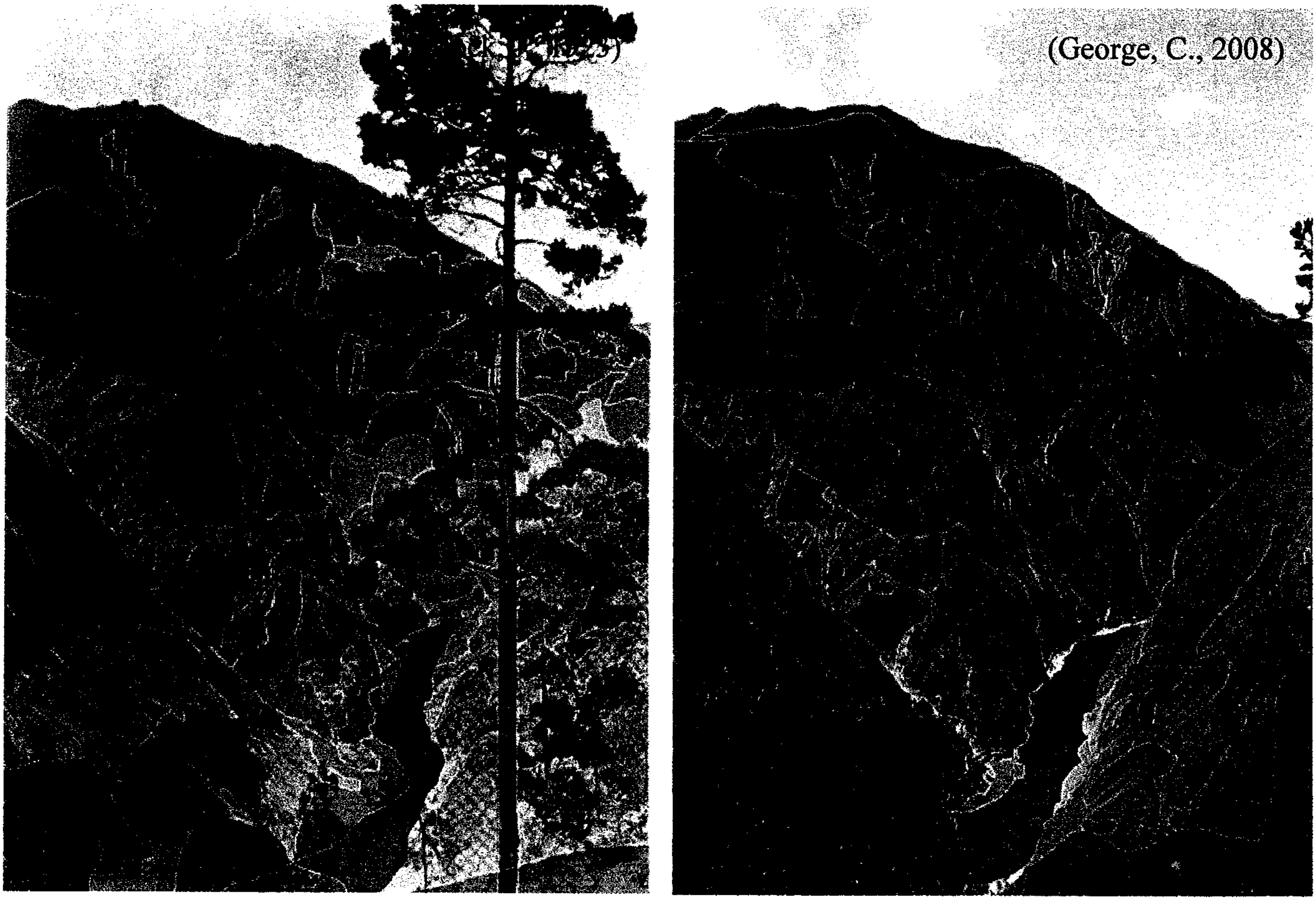


Table D.8 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #20

Photo Set # 20 Landscape Characteristics	Presence/Absence Rock (1923)	George (2008)	Trend	Degrees of Change
Settlement	A	A	Stable	N/A
Transportation Infrastructure	A	A	Stable	N/A
Industrial Infrastructure	A	A	Stable	N/A
Agricultural Lands	A	A	Stable	N/A
Grazing Lands	A	A	Stable	N/A
Forest Plantations	A	A	Stable	N/A
Human-Impacted Vegetation	A	A	Stable	N/A
Human-Impacted Erosion	A	A	Stable	N/A
Human-Impacted Wetland	A	A	Stable	N/A
Rock	P	P	Decreasing	Moderate
Mass Wasting/Erosion	P	P	Decreasing	Slight
Glaciers/Snow	A	A	Stable	N/A
Fluvial	P	P	Increasing	Slight
Fluvial Geomorphology	P	P	Stable	N/A
High Altitude Geomorphology	A	A	Stable	N/A
Arid Grassland	P	A	Decreasing	Moderate
Arid Shrubland	P	P	Decreasing	Extensive
Warm *Pinus* Forest	P	P	Decreasing	Extensive
Mixed Forest	P	P	Increasing	Extensive
Evergreen *Quercus* Forest	P	P	Increasing	Extensive
Subalpine Forest	P	P	Stable	N/A

Photo Set #21

Figure D.10 Photo Set #21 with colour-coded landscape classifications overlaid.

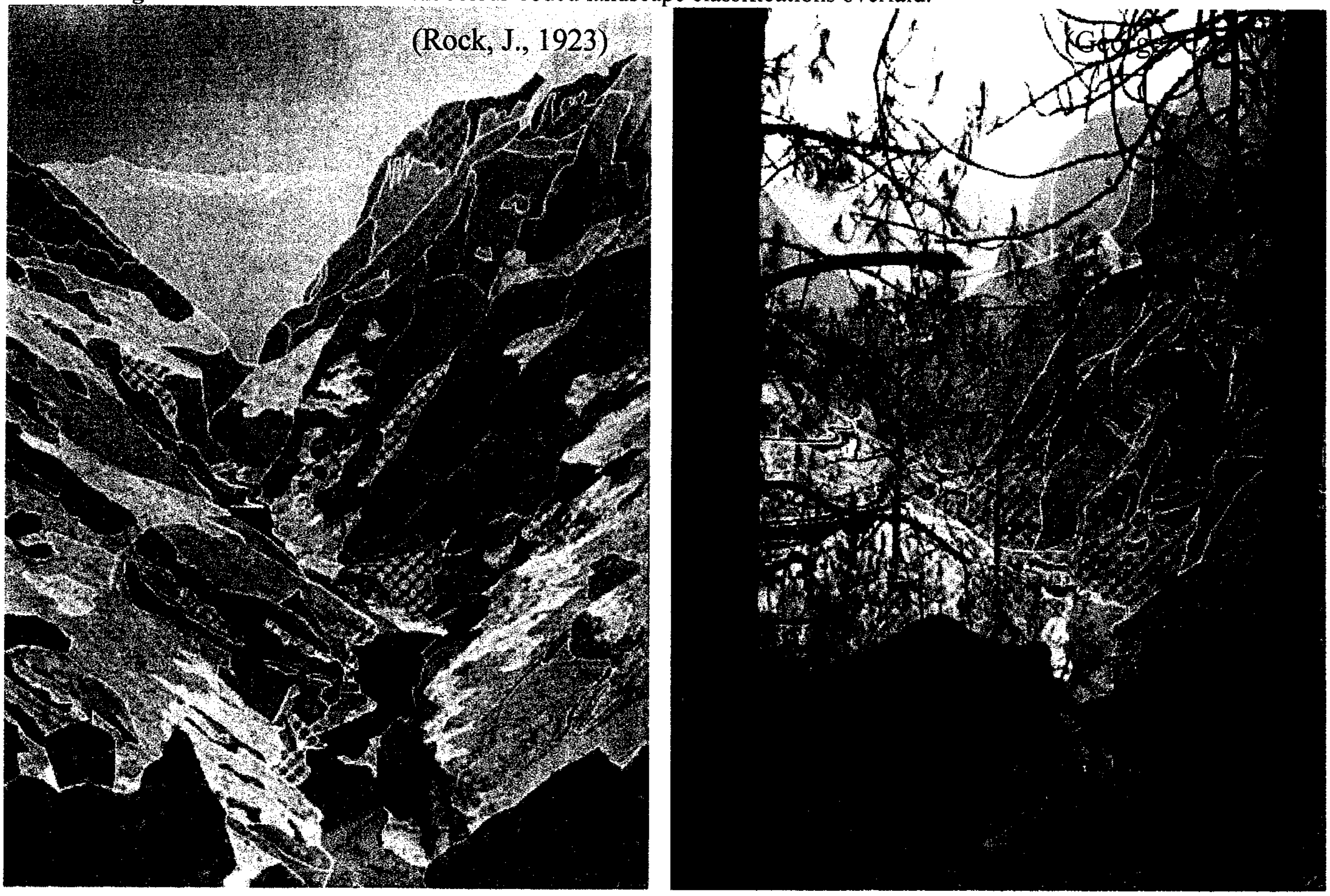


Table D.9 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #21

Photo Set # 21 Landscape Characteristics	Presence/Absence Rock (1923)	George (2008)	Trend	Degrees of Change
Settlement	A	A	Stable	N/A
Transportation Infrastructure	A	P	Increasing	Moderate
Irrigation Infrastructure	A	A	Stable	N/A
Agricultural Lands	A	A	Stable	N/A
Grazing Lands	A	A	Stable	N/A
Forest Plantations	A	A	Stable	N/A
Human Impacted Vegetation	A	A	Stable	N/A
Human Impacted Erosion	A	P	Increasing	Moderate
Rock	P	P	Decreasing	Moderate
Mass Wasting/Erosion	P	P	Increasing	Slight
Glaciers/Snow	P	A	Decreasing	Slight
Fluvial	P	P	Increasing	Slight
Fluvial Geomorphology	P	P	Decreasing	Slight
High Altitude Geomorphology	P	P	Stable	N/A
Arid Grassland	P	P	Decreasing	Moderate
Arid Shrubland	P	P	Decreasing	Extensive
[illegible] Savannah	A	A	Stable	N/A
Wetlands	P	P	Decreasing	Moderate
Warm *Pinus* Forest	P	P	Increasing	Moderate
Mixed Forest	P	P	Increasing	Extensive
Evergreen *Quercus* Forest	A	A	Stable	N/A
Evergreen Broadleaf Forest	A	A	Stable	N/A
Subalpine Forest	P	P	Decreasing	Slight
Alpine Meadow	A	A	Stable	N/A

Photo Set #22

Figure D.11 Photo Set #22 with colour-coded landscape classifications overlaid.

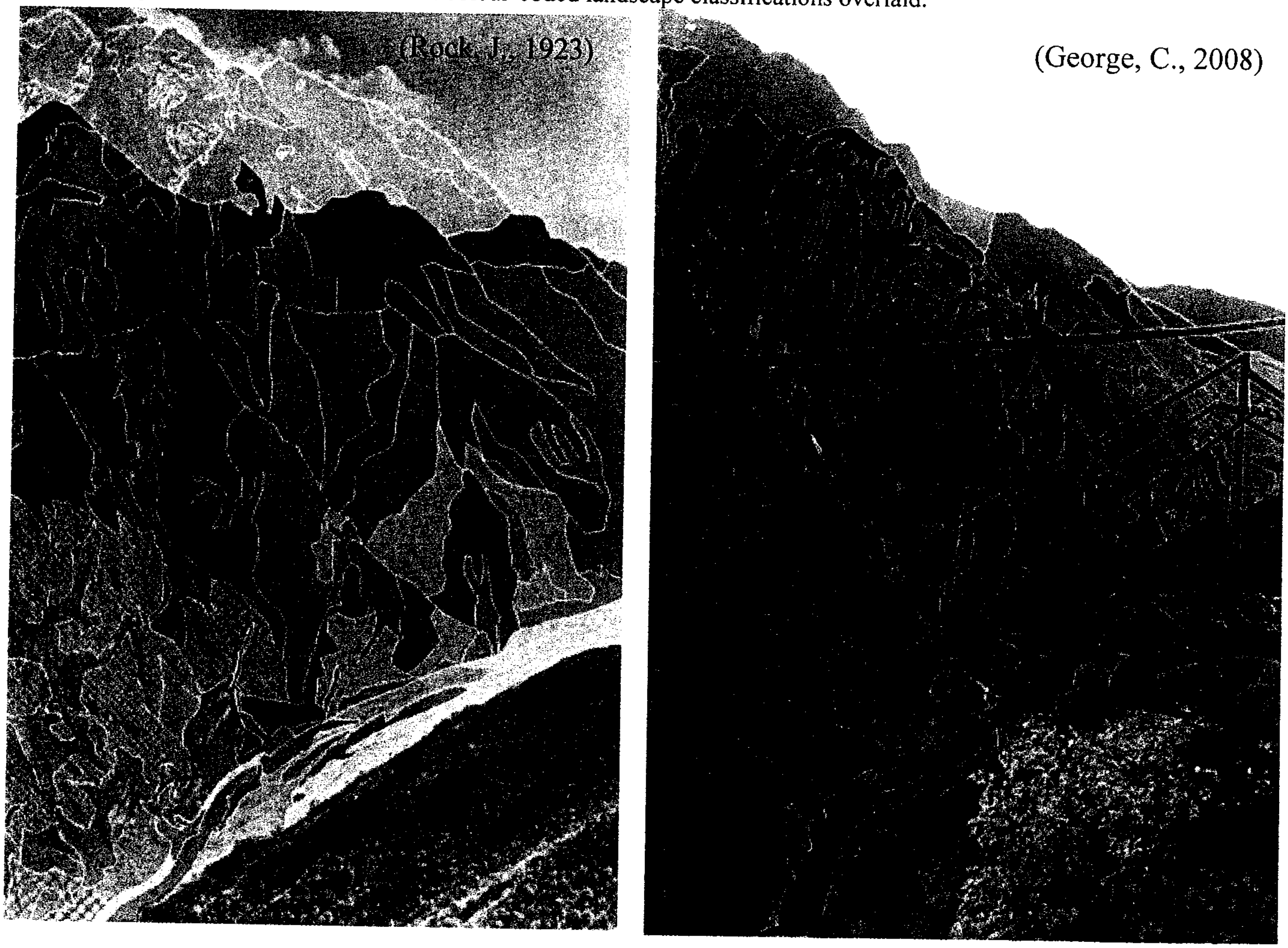


Table D.10 Cataloging Presence/Absence, Trends and Degrees of Change for Photo Set #22

Photo Set # 22 Landscape Characteristics	Presence/Absence Rock (1923)	George (2008)	Trend	Degrees of Change
Settlements	A	A	Stable	N/A
Transportation Infrastructure	A	P	Increasing	Slight
Industrial Infrastructure	A	P	Increasing	Moderate
Agricultural Lands	A	A	Stable	N/A
Grazing Lands	A	A	Stable	N/A
Forest Plantations	A	A	Stable	N/A
Human Impacted Vegetation	A	A	Stable	N/A
Human Impacted Erosion	A	A	Stable	N/A
Human Impacted Wastelands	A	P	Increasing	Moderate
Rock	P	P	Decreasing	Slight
Mass Wasting Erosion	P	P	Increasing	Slight
Glacier/Snow	P	P	Decreasing	Moderate
[illegible]	P	P	Increasing	Slight
Fluvial Geomorphology	P	P	Stable	N/A
High Altitude Geomorphology	P	P	Increasing	Slight
Arid Grassland	P	P	Increasing	Extensive
Arid Shrubland	P	P	Decreasing	Extensive
Woodlands	P	A	Decreasing	Slight
Warm *Pinus* Forest	P	P	Increasing	Slight
Mixed Forest	P	P	Decreasing	Extensive
Evergreen *Quercus* Forest	P	P	Increasing	Extensive
Subalpine Forest	P	P	Decreasing	Moderate

APPENDIX E:
PHOTO ANALYSIS
SIMPLE GRID ANALYSIS

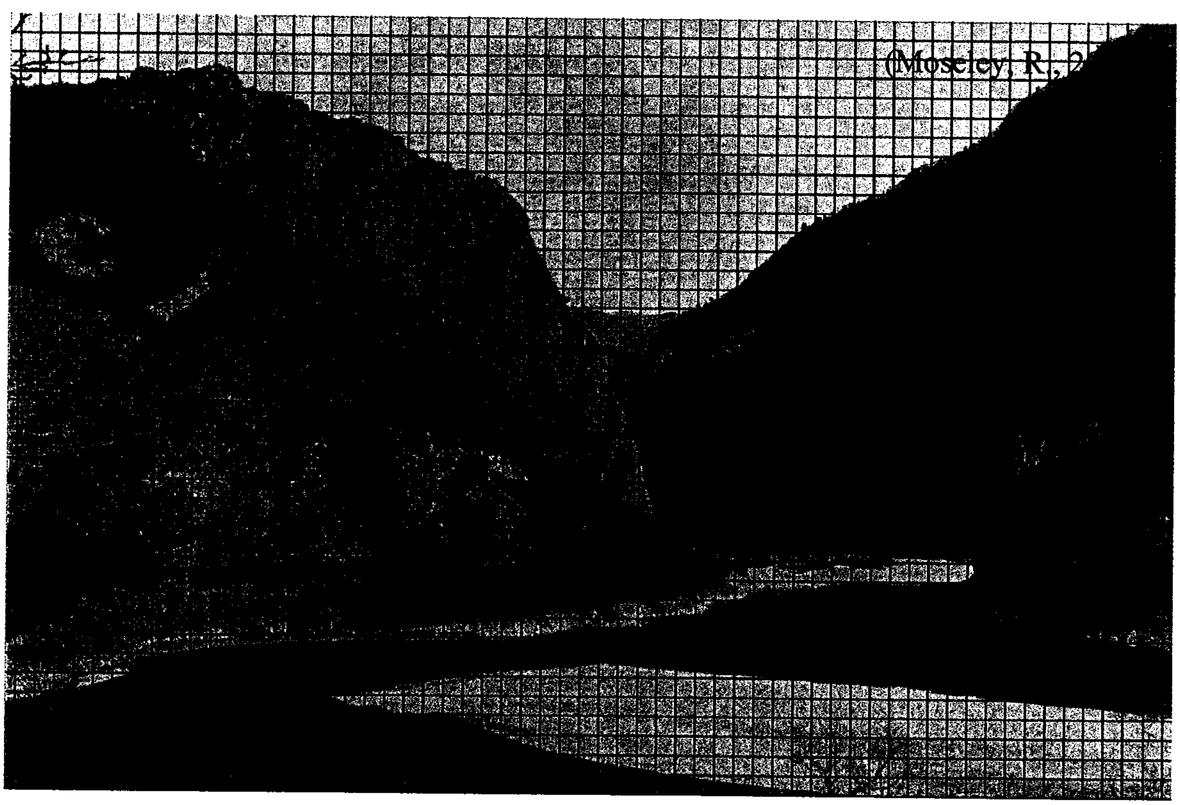
This appendix provides the reader with the results of the Simple Grid Analysis that was conducted on the photo sets that included a photograph taken as part of this study. This method of analysis was conducted according to Hall (2002b) and measures the area covered by each landscape classification on the plane of the photograph. Each landscape classification is highlighted using the colour categories and the number of squares that are occupied by each landscape category is counted to calculate the percentage of photo area that is represented by each specific landscape classification. This appendix provides the photographs with the simple grid overlaid, as well as tables showing the value of each landscape classification through total number of squares and percentage area occupied by each landscape classification. Each landscape classification is represented on the photographs according to the legend below.

Figure E.1 The legend for the colour-coded landscape classifications.

Landscape Classifications

- Residential/Commercial Infrastructure
- Transportation Infrastructure
- Industrial/Hydro Infrastructure
- Agricultural Lands
- Pasture Lands
- Forest Plantations
- Human-Impacted Vegetation
- Human-Induced Erosion
- Human-Impacted Wasteland
- Exposed Rock/Stable Soil
- Erosion/Mass Wasting
- Fluvial/Hydrology
- Fluvial Geomorphology
- Glaciers/Snow
- High-Altitude Geomorphology
- Arid Grassland
- Arid Shrubland
- Pinus Savannah
- Woodland
- Warm Pinus Forest
- Mixed Forest
- Evergreen Quercus Forest
- Evergreen Broadleaf Forest
- Subalpine Forest
- Alpine Heath/Alpine Meadow
- Undetermined
- Mixture of Landscape Classifications

Figure E.2.1-3 Photo Set #1 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923), Moseley (2003) and George (2008).



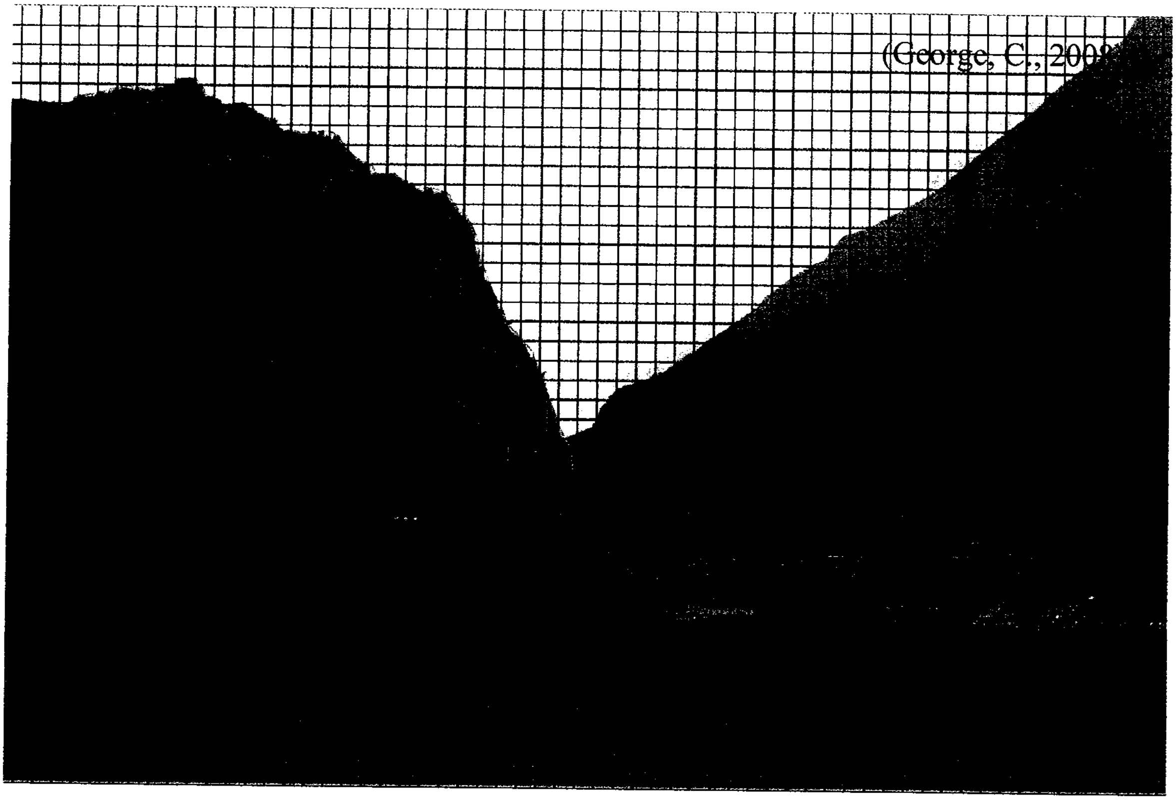


Figure E.2.4 The changing percentage photo area of each landscape classification through time.

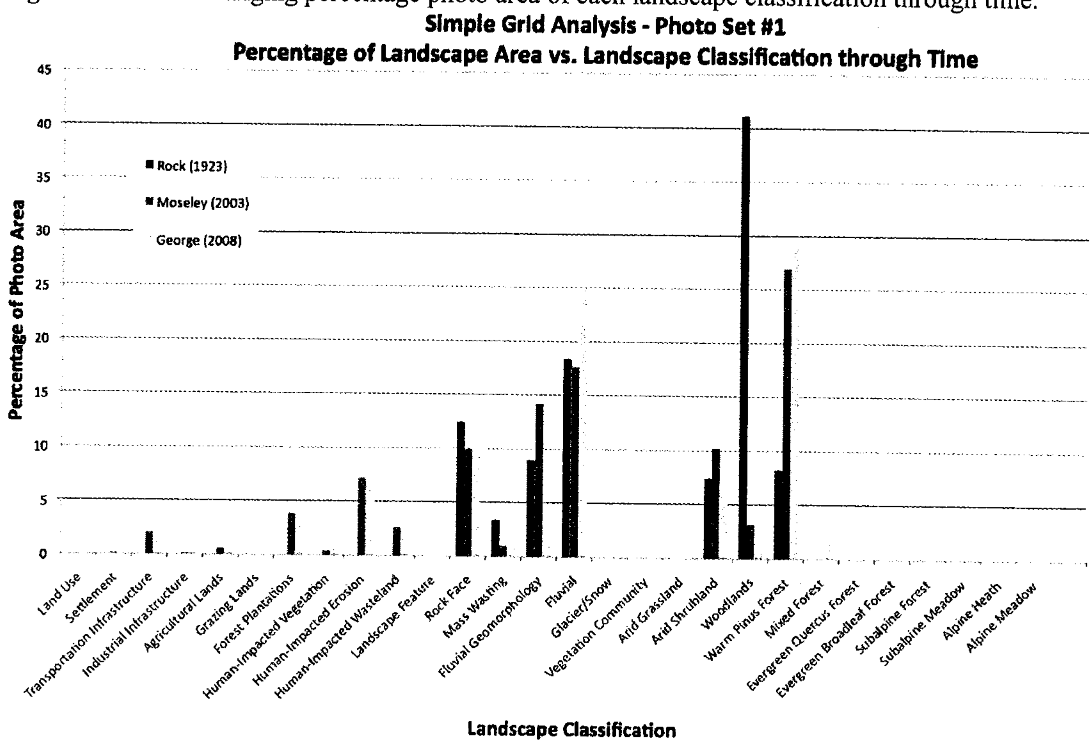
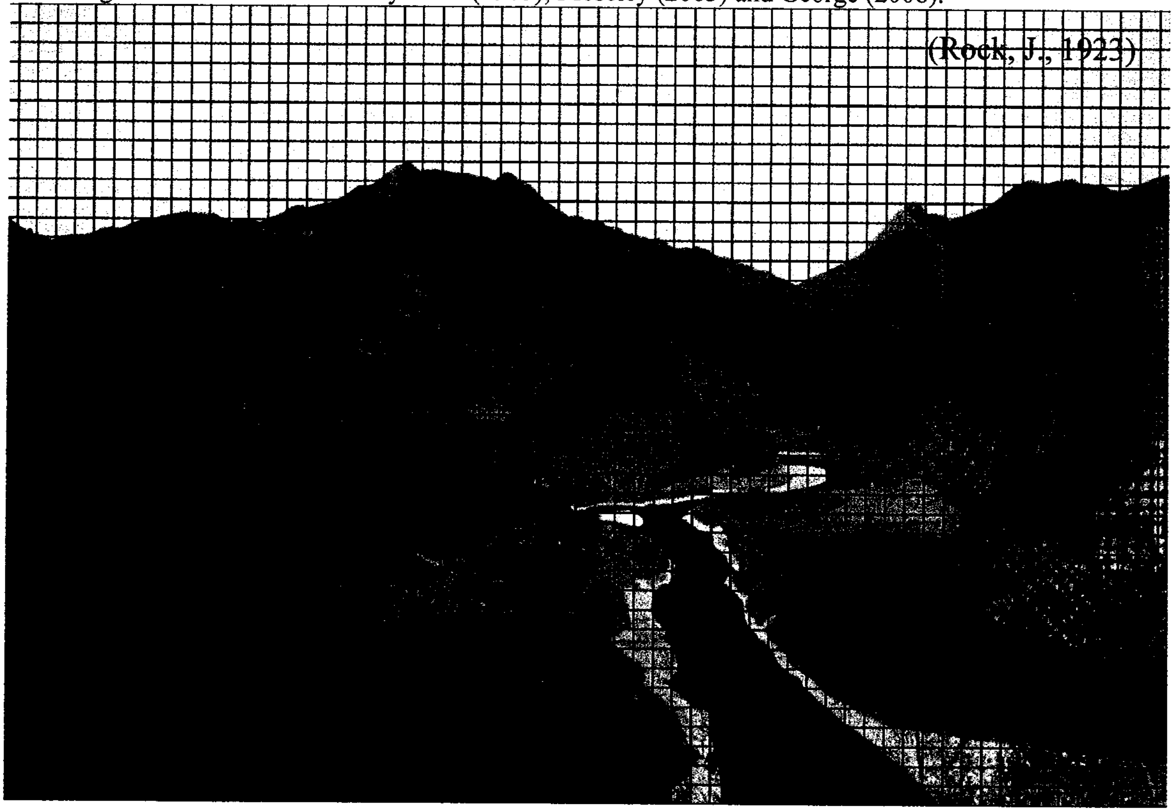
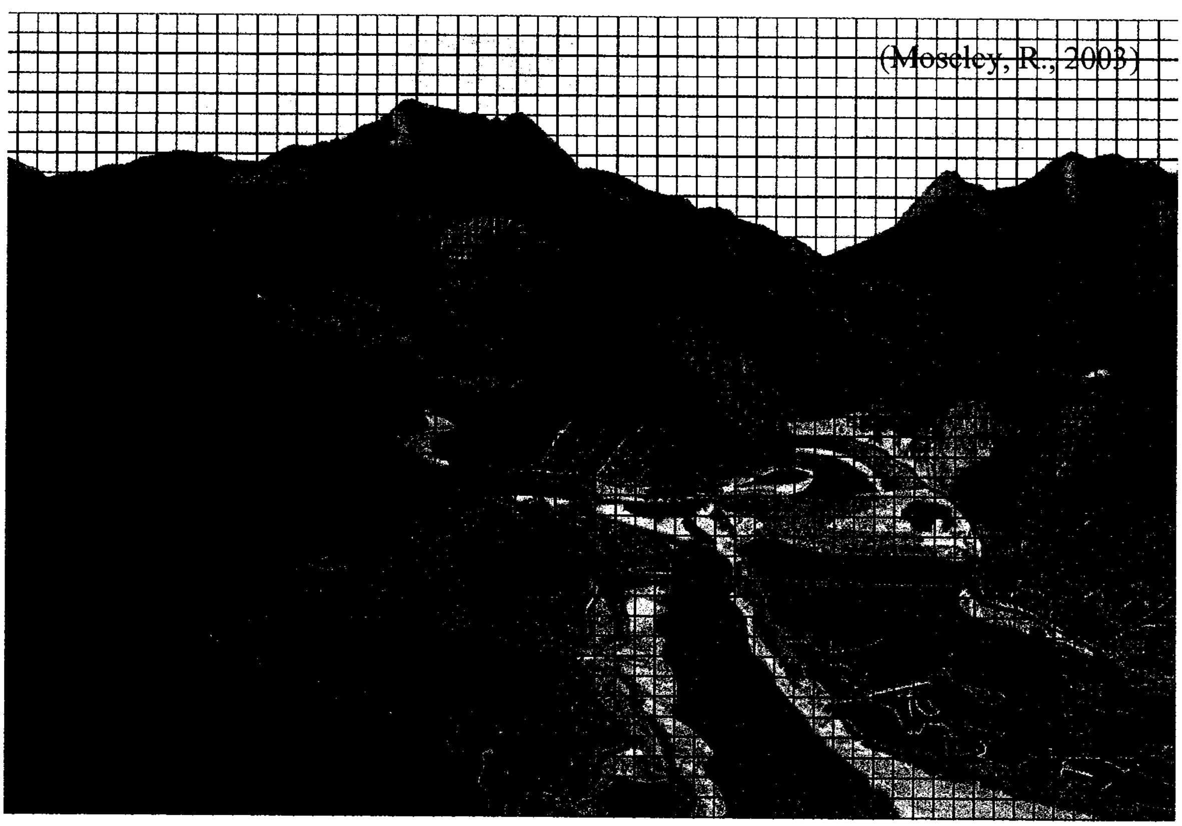


Table E.1 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #1

Photo Set #1 - Simple	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
[illegible]						
Settlement	0	0.00	1	0.07	1	0.07
Transportation Infrastructure	0	0.00	30	2.03	29	2.01
Industrial Infrastructure	0	0.00	1	0.07	30	2.08
Agricultural Land	0	0.00	9	0.61	9	0.62
Grazing Lands	0	0.00	0	0.00	0	0.00
Forest Plantation	0	0.00	57	3.86	53	3.67
Human Impacted Vegetation	0	0.00	6	0.41	28	1.94
Human Impacted Erosion	0	0.00	106	7.17	92	6.37
Human Impacted Wasteland	0	0.00	39	2.64	46	3.19
[illegible]						
Rock Face	188	12.48	147	9.95	146	10.11
Mass Wasting	51	3.38	15	1.02	25	1.73
Fluvial Geomorphology	135	8.96	210	14.21	46	3.19
Fluvial	277	18.38	261	17.66	360	24.93
Glacier/Snow	0	0.00	0	0.00	0	0.00
[illegible]						
Arid Grassland	0	0.00	0	0.00	0	0.00
Arid Shrubland	112	7.43	151	10.22	104	7.20
Woodlands	620	41.14	47	3.18	25	1.73
Warm *Pinus* Forest	124	8.23	398	26.93	416	28.81
Mixed Forest	0	0.00	0	0.00	34	2.36
Evergreen *Quercus* Forest	0	0.00	0	0.00	0	0.00
Evergreen Broadleaf Forest	0	0.00	0	0.00	0	0.00
Subalpine Forest	0	0.00	0	0.00	0	0.00
Subalpine Meadow	0	0.00	0	0.00	0	0.00
Alpine Heath	0	0.00	0	0.00	0	0.00
Alpine Meadow	0	0.00	0	0.00	0	0.00
[illegible]	1507	100.00	1478	100.00	1444	100.00

Figure E.3.1-3 Photo Set #3 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923), Moseley (2003) and George (2008).





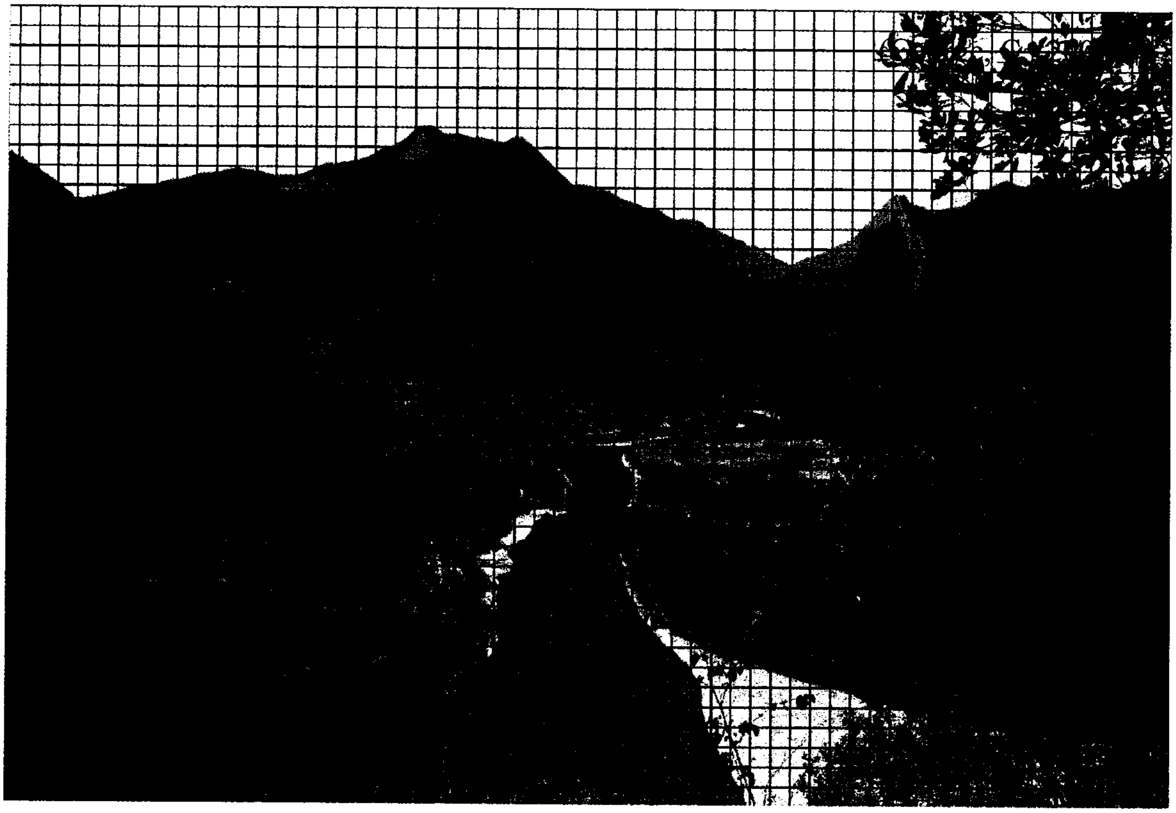


Figure E.3.4 The changing percentage photo area of each landscape classification through time.

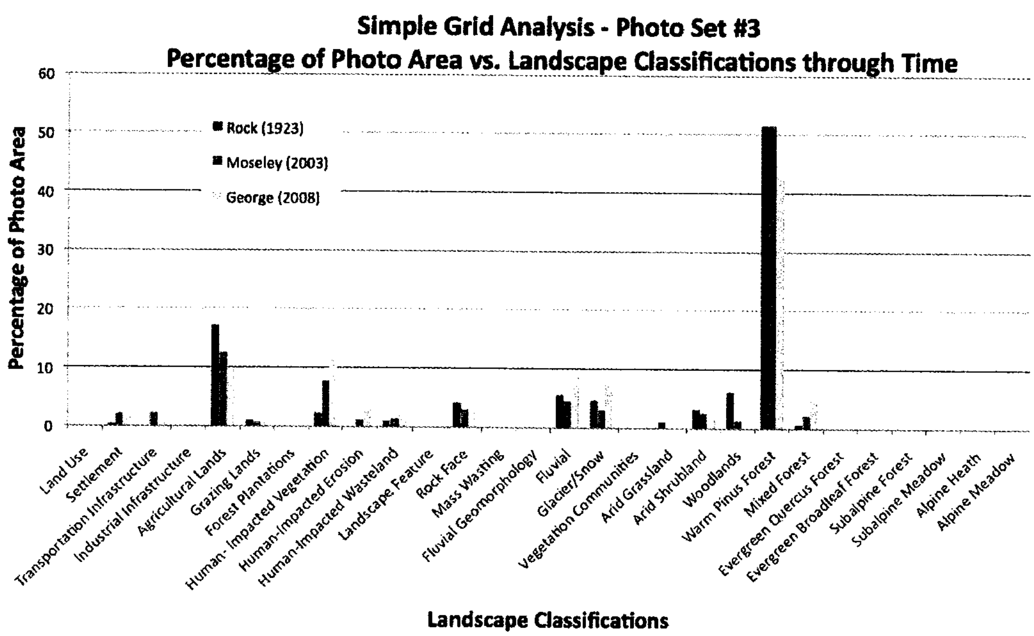
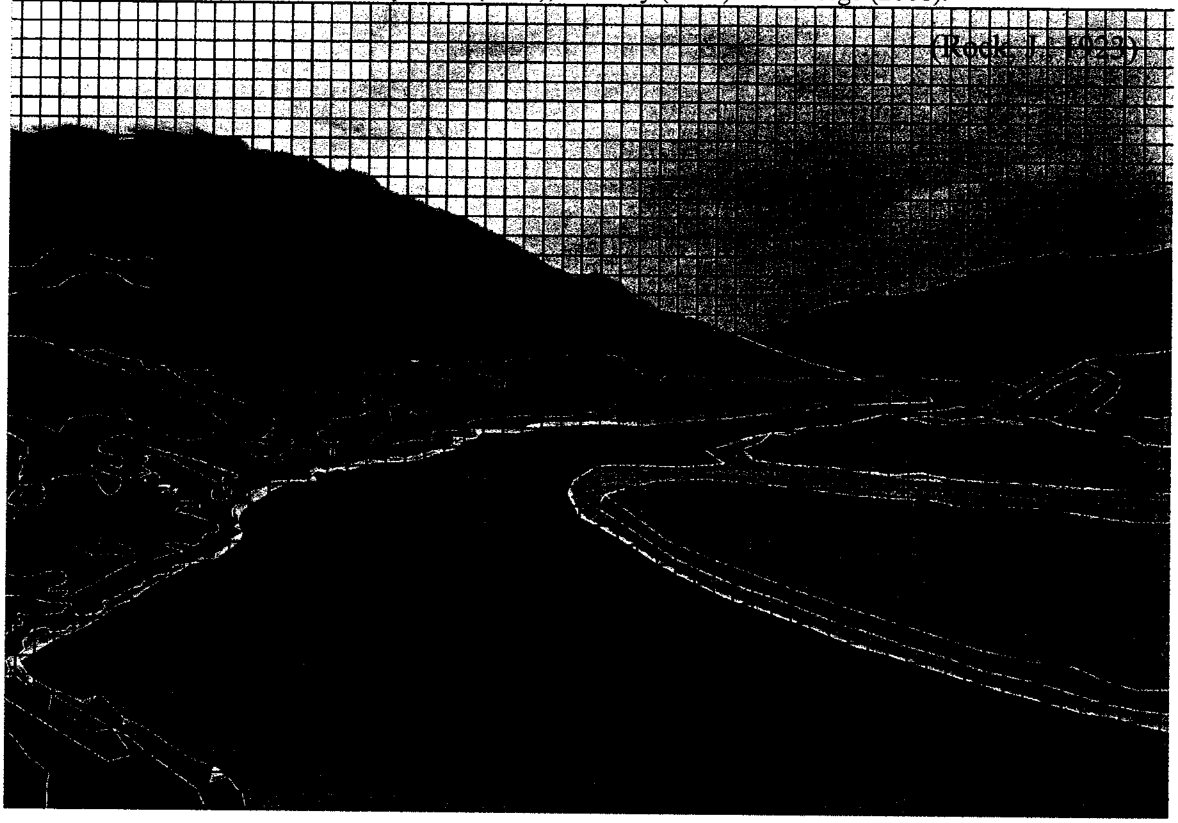
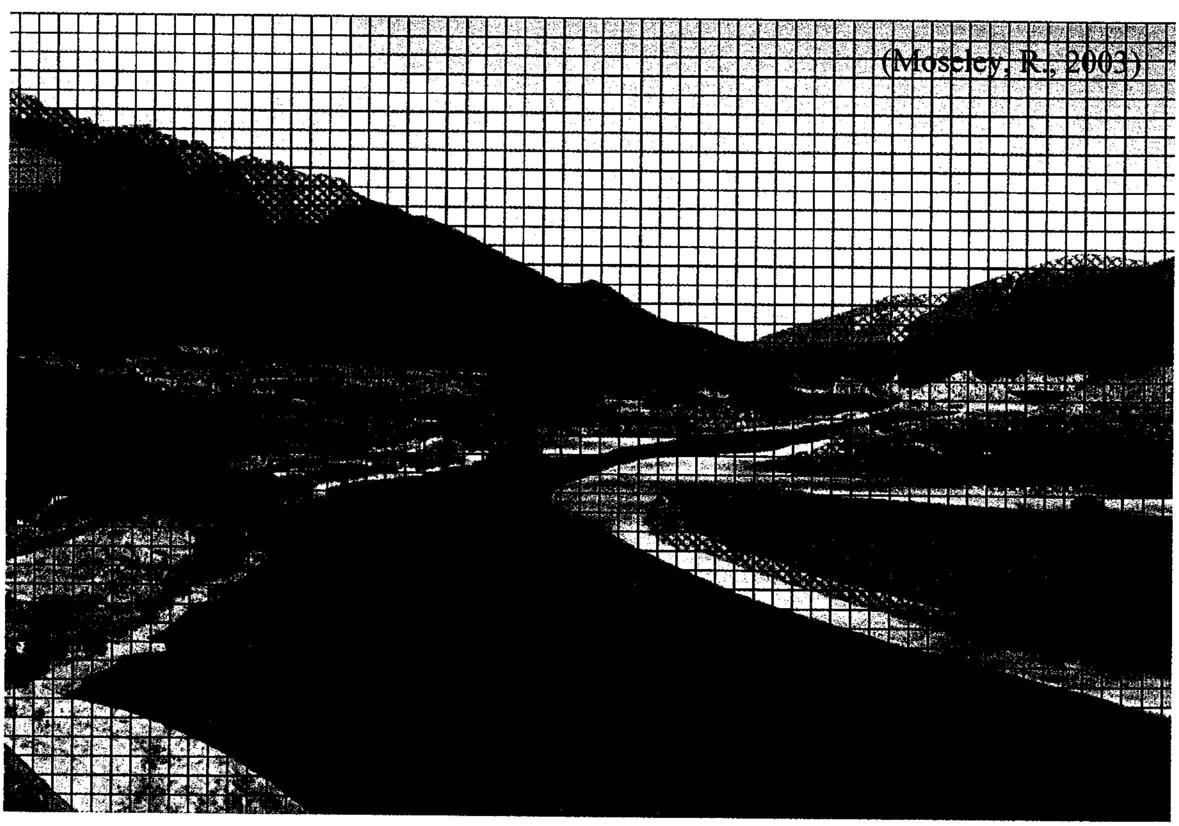


Table E.2 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #3

Photo Set #3 - Simple	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
[illegible]						
Settlement	7	0.43	38	2.15	29	1.59
Transportation Infrastructure	0	0.00	41	2.32	20	1.10
Industrial Infrastructure	0	0.00	0.5	0.03	3	0.16
Agricultural Lands	283	17.18	222	12.57	174	9.53
Grazing Lands	18	1.09	14	0.79	12	0.66
Human Impacted Vegetation	38	2.31	138	7.82	201	11.01
Human Impacted Erosion	0	0.00	21	1.19	59	3.23
Human Impacted Wasteland	16	0.97	25	1.42	37	2.03
[illegible]						
Rock Face	69	4.19	53	3.00	54	2.96
Mass Wasting	14	0.85	62	3.51	65	3.56
Fluvial Geomorphology	77	4.68	53	3.00	132	7.23
[illegible]	93	5.65	81	4.59	155	8.49
[illegible]						
Arid Grassland	17	1.03		0.00	0	0.00
Arid Shrubland	53	3.22	46	2.61	45	2.46
Woodlands	102	6.19	24	1.36	0	0.00
[illegible] *Pinus* Forest	849	51.55	909	51.49	754	41.29
Mixed Forest	11	0.67	38	2.15	86	4.71
[illegible]	1647	100.00	[illegible]	100.00	1826	100.00

Figure E.4.1-3 Photo Set #8 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923), Moseley (2003) and George (2008).





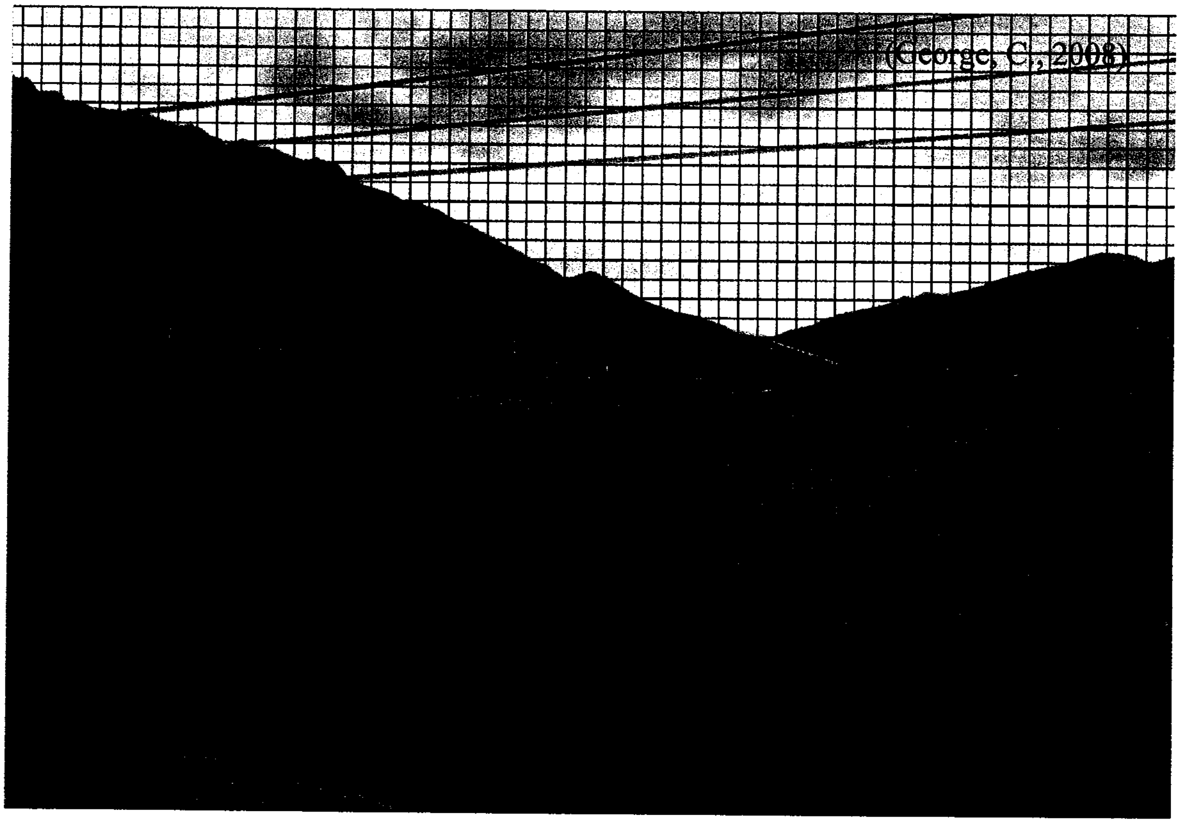


Figure E.4.4 The changing percentage photo area of each landscape classification through time.

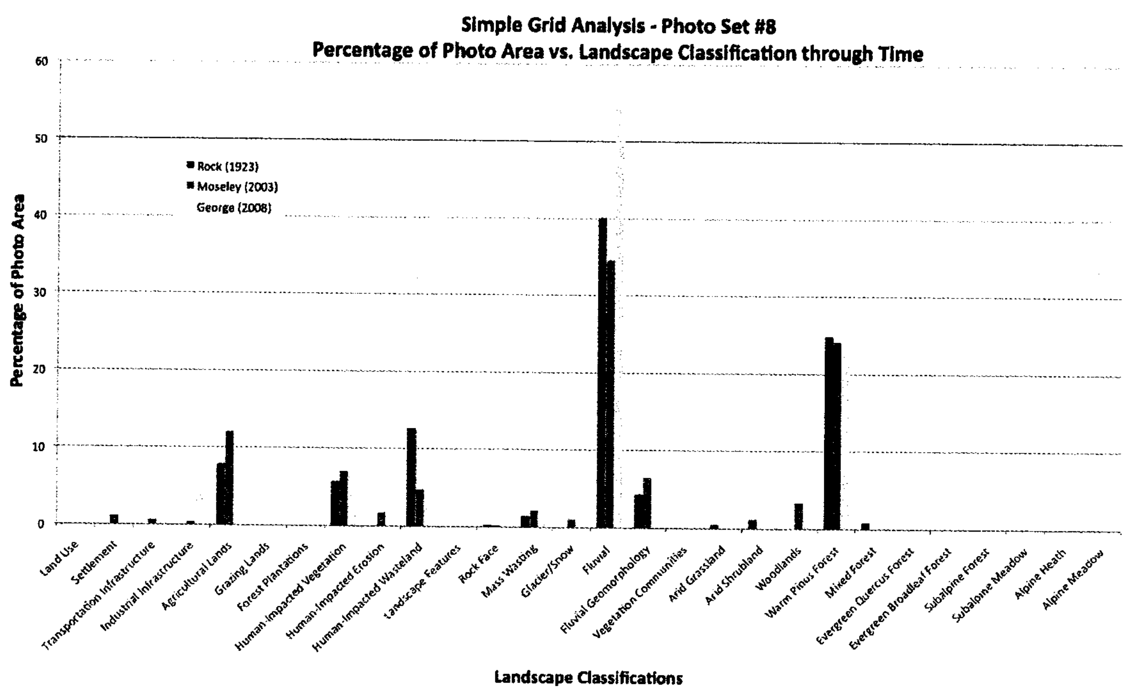
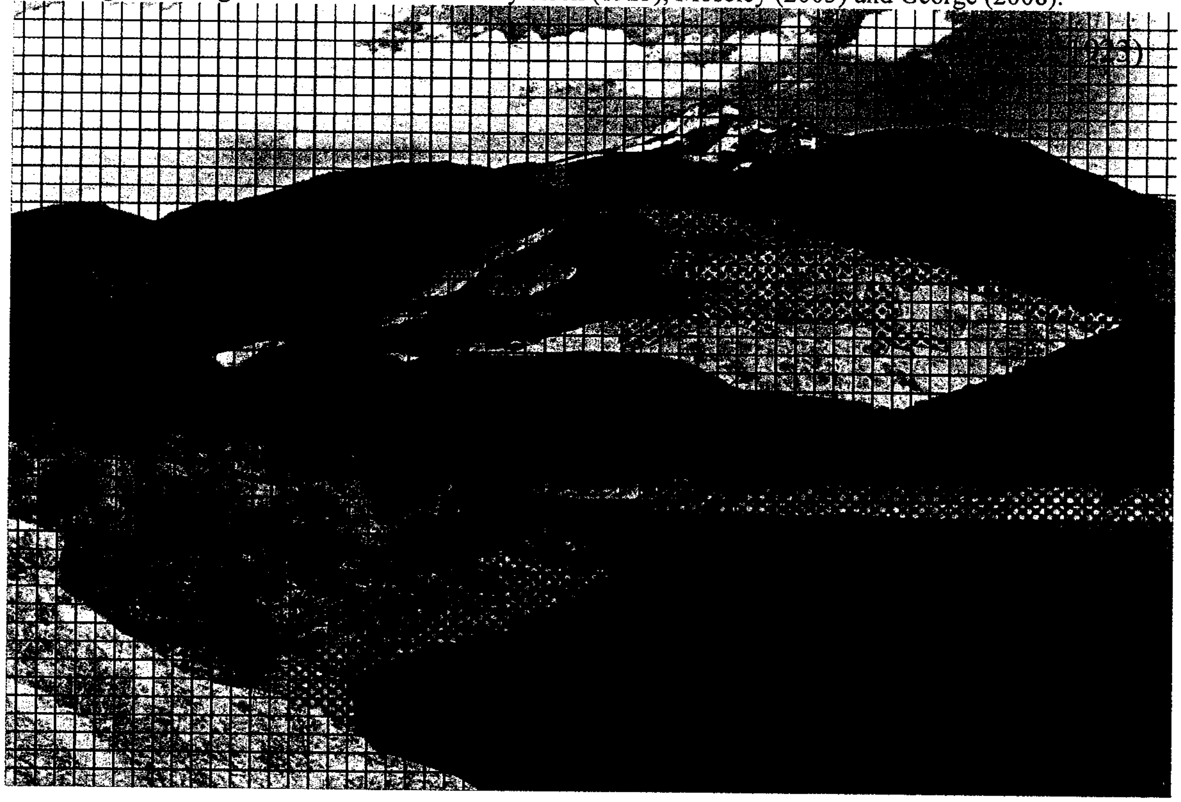
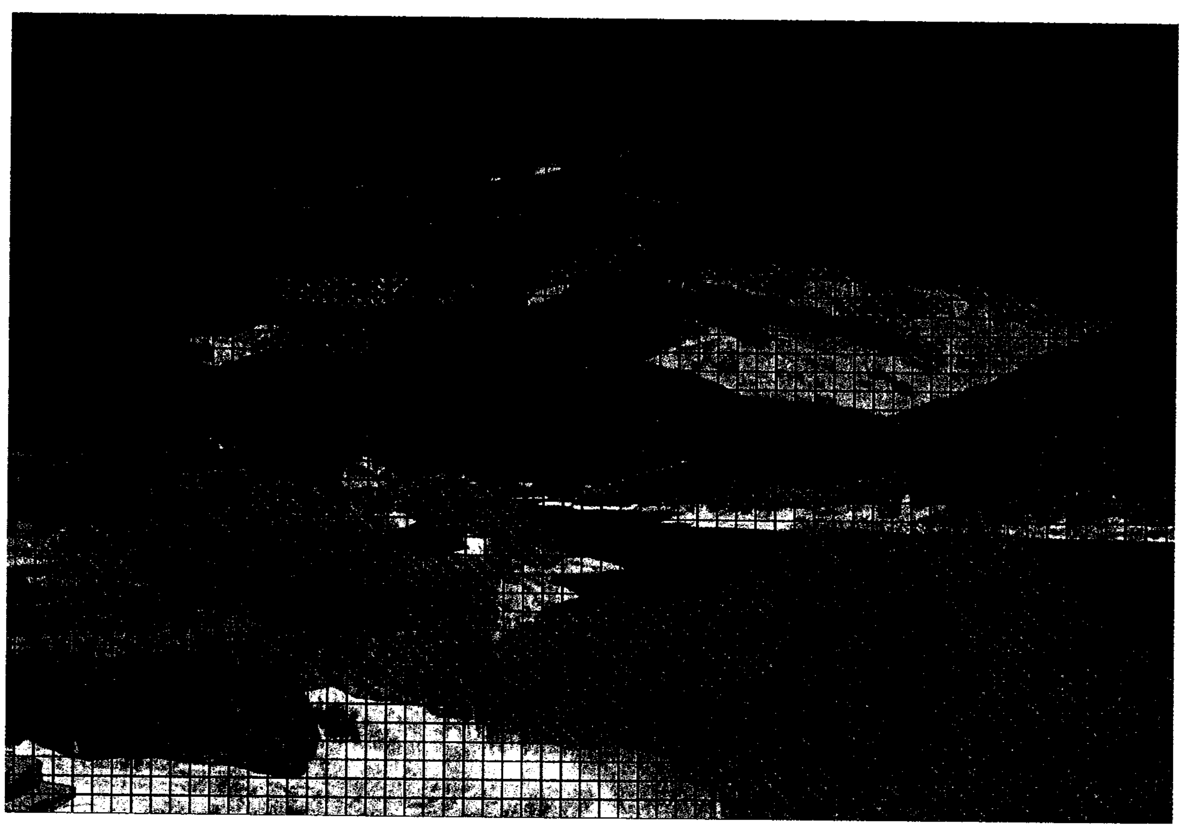


Table E.3 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #8

Photo Set #8 - Simple	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
[illegible]						
Settlement	0	0.00	20	1.11	7	0.49
Transportation Infrastructure	0	0.00	12	0.66	7	0.49
Industrial Infrastructure	0	0.00	7	0.39	61	4.27
Agricultural Lands	144	7.93	218	12.06	39	2.73
Human-Impacted Vegetation?	105	5.78	127	7.03	92	6.44
Human-Impacted Erosion	0	0.00	32	1.77	9	0.63
Human-Impacted Wasteland	230	12.67	87	4.82	49	3.43
[illegible]						
Rock Face	5	0.28	4	0.22	0	0.00
Mass Wasting	27	1.49	39	2.16	27	1.89
Glacier/Snow	0	0.00	19	1.05	0	0.00
[illegible]	728	40.09	626	34.64	787	55.07
Fluvial Geomorphology	79	4.35	118	6.53	12	0.84
[illegible]						
Alpine Grassland	9	0.50	0	0.00	0	0.00
Alpine Shrubland	22	1.21	0	0.00	0	0.00
Wetlands	0	0.00	61	3.38	10	0.70
Warm/Dry Forest	452	24.89	437	24.18	329	23.02
Mixed Forest	15	0.83	0	0.00	0	0.00
[illegible]	[illegible]	100.00	[illegible]	100.00	[illegible]	100.00

Figure E.5.1-3 Photo Set #14 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923), Moseley (2003) and George (2008).





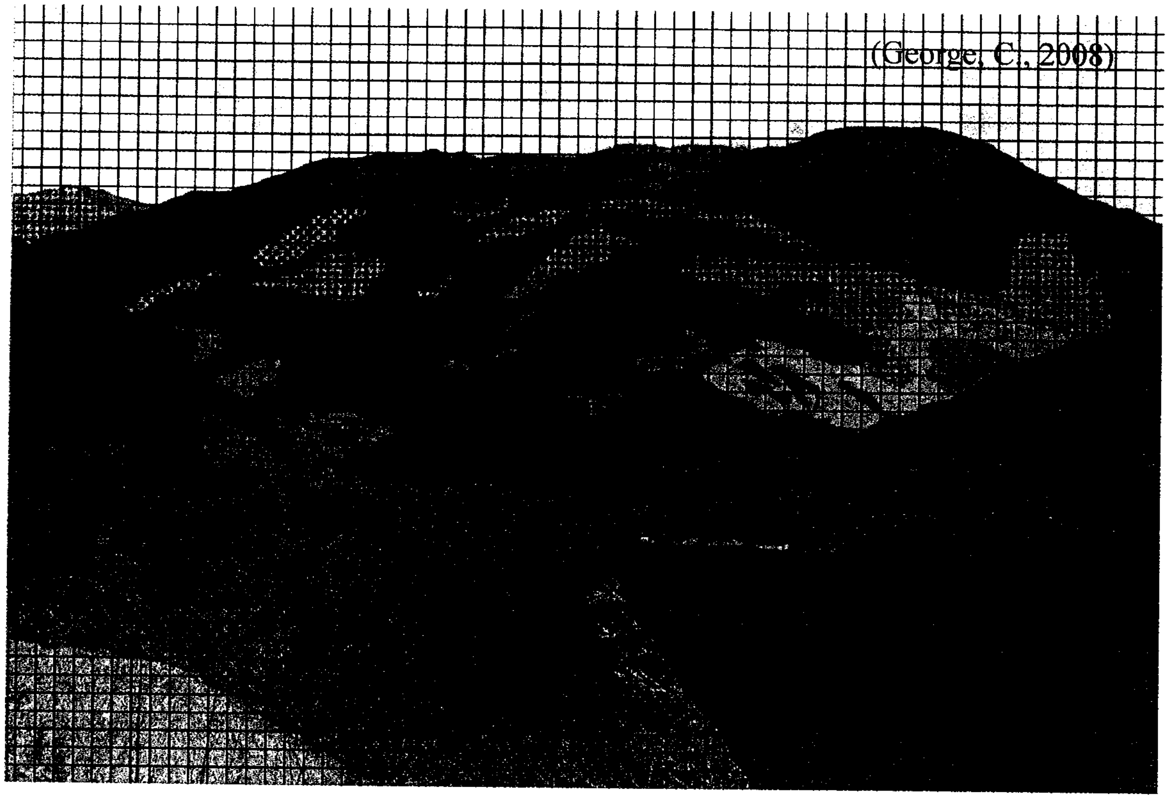


Figure E.5.4 The changing percentage photo area of each landscape classification through time.

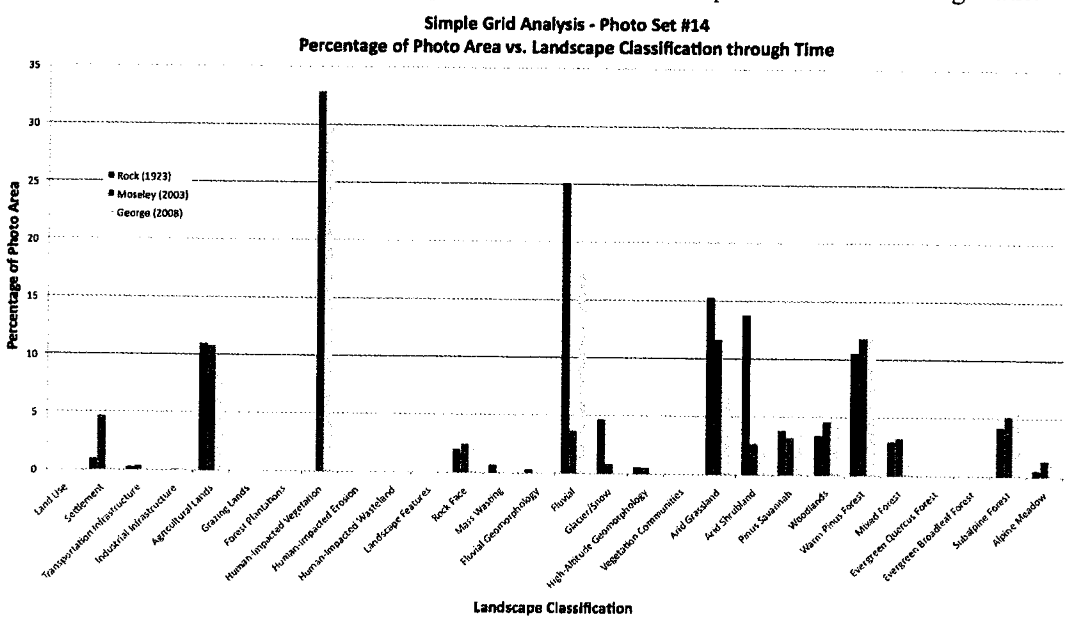
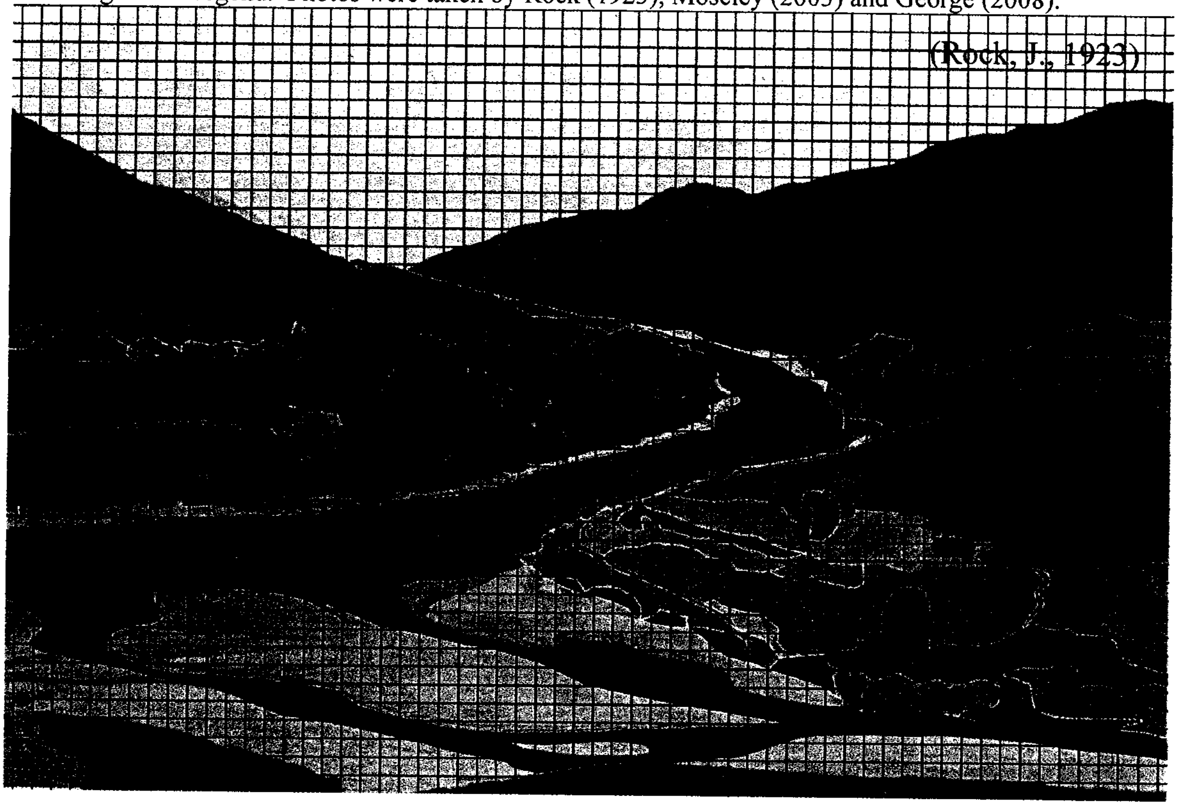
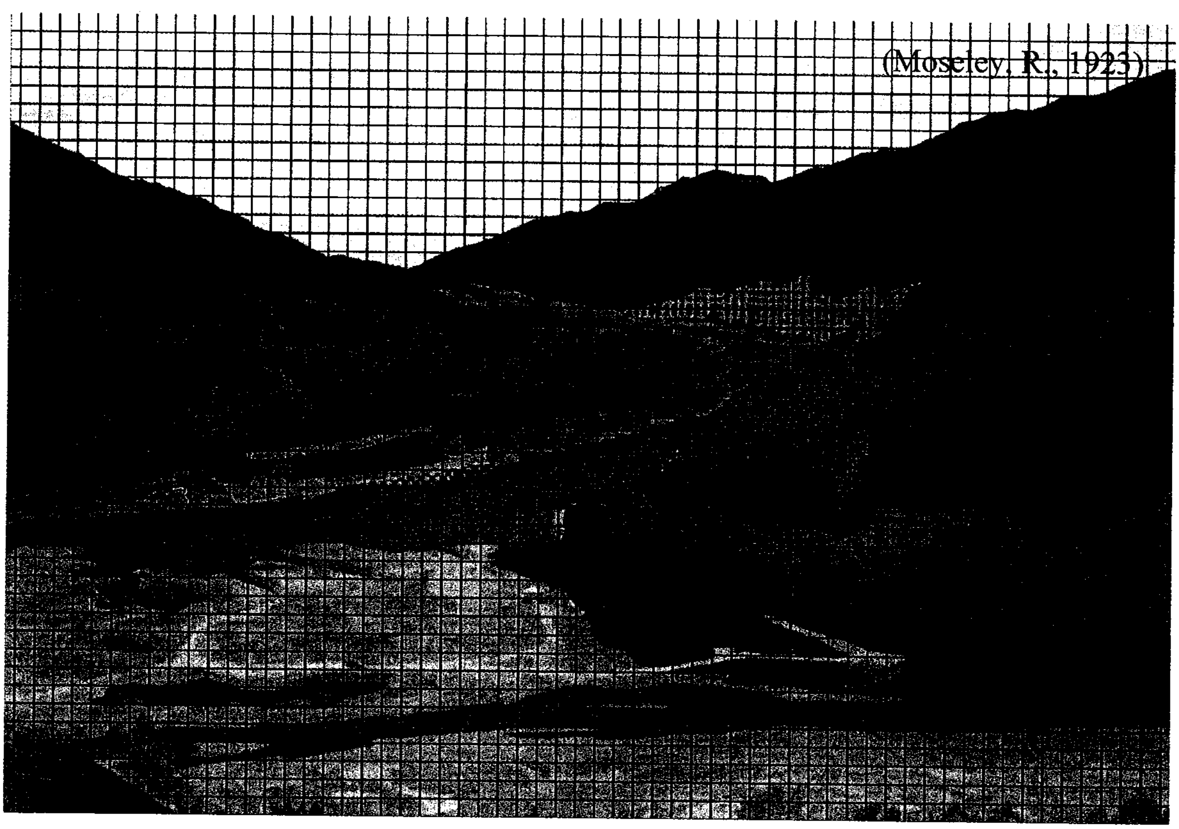


Table E.4 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #14

Photo Set #14 - Simple	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
Settlement	18	0.96	87	4.67	15	0.83
Transportation Infrastructure	5	0.27	7	0.38	2	0.11
Industrial Infrastructure	0	0.00	1	0.05	5	0.28
Agricultural Lands	206	10.96	201	10.79	175	9.71
Human Impacted Vegetation	0	0.00	612	32.85	535	29.67
Rock Face	38	2.02	46	2.47	43	2.39
Mass Wasting	13	0.69	0	0.00	0	0.00
Fluvial Geomorphology	88	4.68	16	0.86	7	0.40
Fluvial	472	25.11	69	3.70	312	17.30
Glacier/Snow	6	0.32	0	0.00	0	0.00
Higher Altitude Geomorphology	11	0.59	10	0.54	0	0.00
Arid Grassland	287	15.27	217	11.65	130	7.21
Arid Shrubland	259	13.78	50	2.68	38	2.11
Pinus Savannah	72	3.83	60	3.22	69	3.83
Woodlands	64	3.40	86	4.62	85	4.71
Warm *Pinus* Forest	198	10.53	220	11.81	212	11.76
Mixed Forest	55	2.93	60	3.22	51	2.83
Subalpine Forest	79	4.20	96	5.15	101	5.60
Alpine Meadow	9	0.48	25	1.34	30	1.66
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure E.6.1-3 Photo Set #16 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923), Moseley (2003) and George (2008).





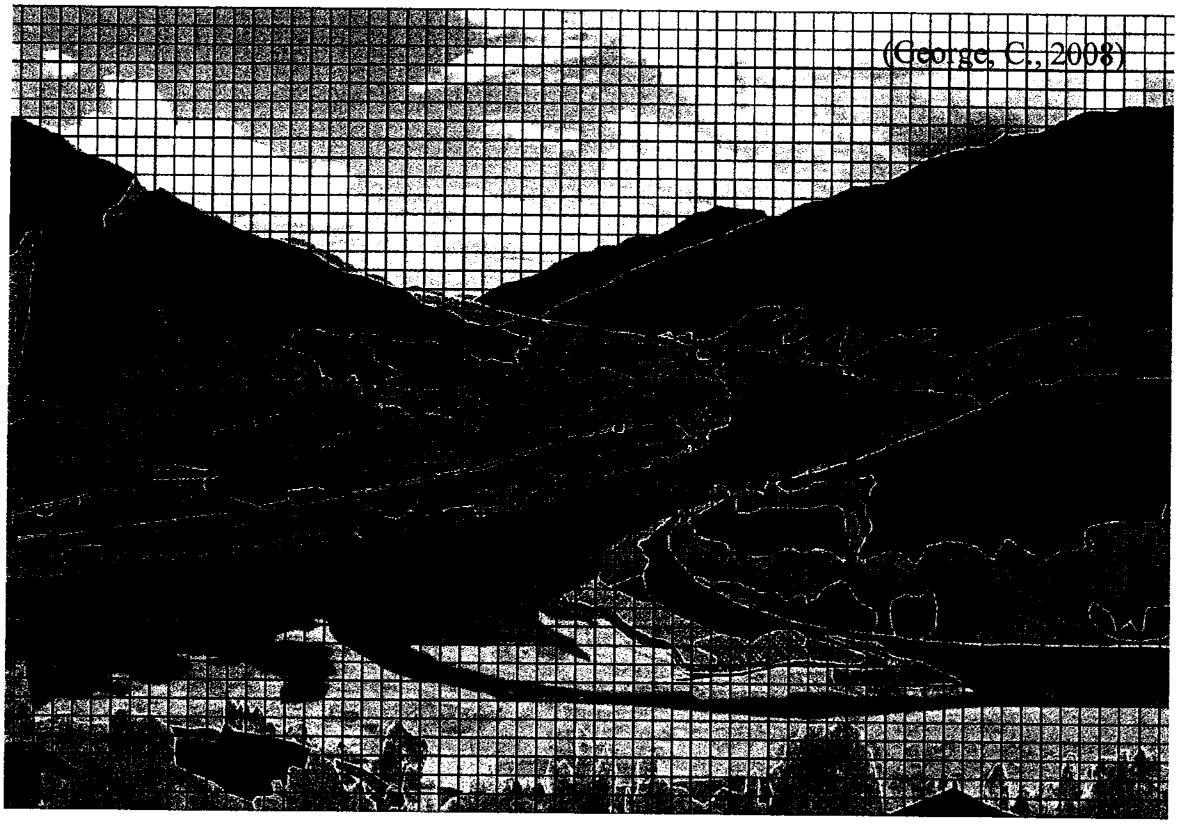


Figure E.6.4 The changing percentage photo area of each landscape classification through time.

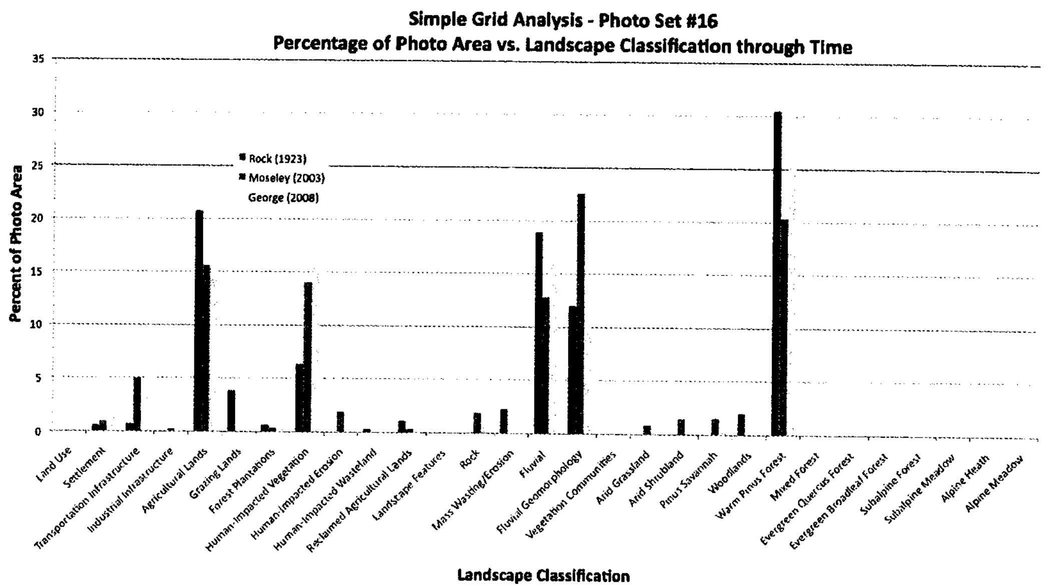
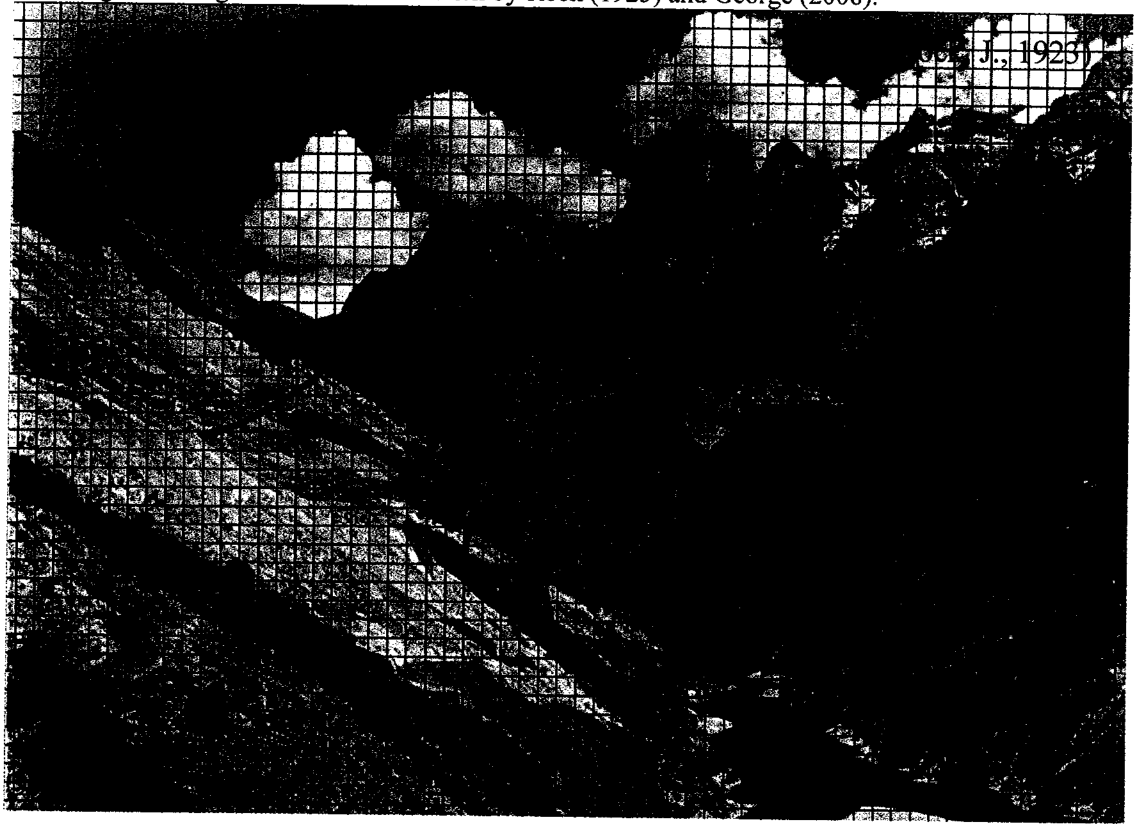


Table E.5 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #16

Photo Set # 16- Simple	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
[illegible]						
Settlement	6	0.32	16	0.89	26	1.44
Transportation Infrastructure	2	0.11	113	6.27	50	2.76
Industrial Infrastructure	0	0.00	3	0.17	5	0.28
Agricultural Lands	489	26.09	288	12.65	279	15.41
Grazing Lands	18	0.96	0	0.00	0	0.00
Forest Plantations	10	0.53	0	0.00	12	0.66
Human Impacted Vegetation	104	5.55	283	15.71	321	17.74
Human Impacted Erosion	0	0.00	7	0.39	7	0.39
Human Impacted Wasteland	47	2.51	30	1.67	29	1.60
Reclaimed Agricultural Lands	0	0.00	8	0.44	8	0.44
[illegible]						
Rock	22	1.17	42	2.33	20	1.11
[illegible]	389	20.76	228	12.65	375	20.72
[illegible]	313	16.70	404	22.42	234	12.93
[illegible]						
Arid Grassland	0	0.00	0	0.00	0	0.00
Arid Shrubland	0	0.00	46	2.55	0	0.00
[illegible]	0	0.00	0	0.00	19	1.05
Woodlands	33	1.76	14	0.78	10	0.55
[illegible] *Pinus* Forest	441	23.53	380	21.09	415	22.93
[illegible]	[illegible]	100.00	[illegible]	100.00	[illegible]	100.00

Figure E.7.1,2 Photo Set #17 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923) and George (2008).



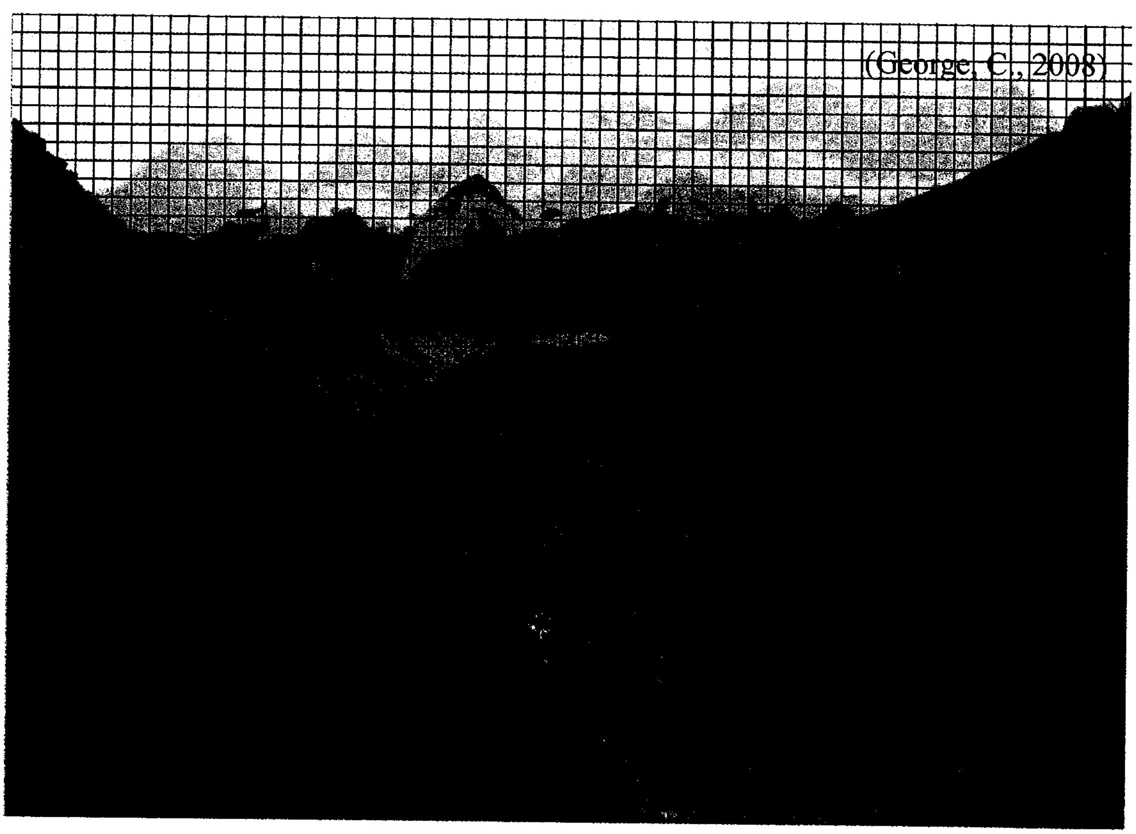


Figure E.7.3 The changing percentage photo area of each landscape classification through time.

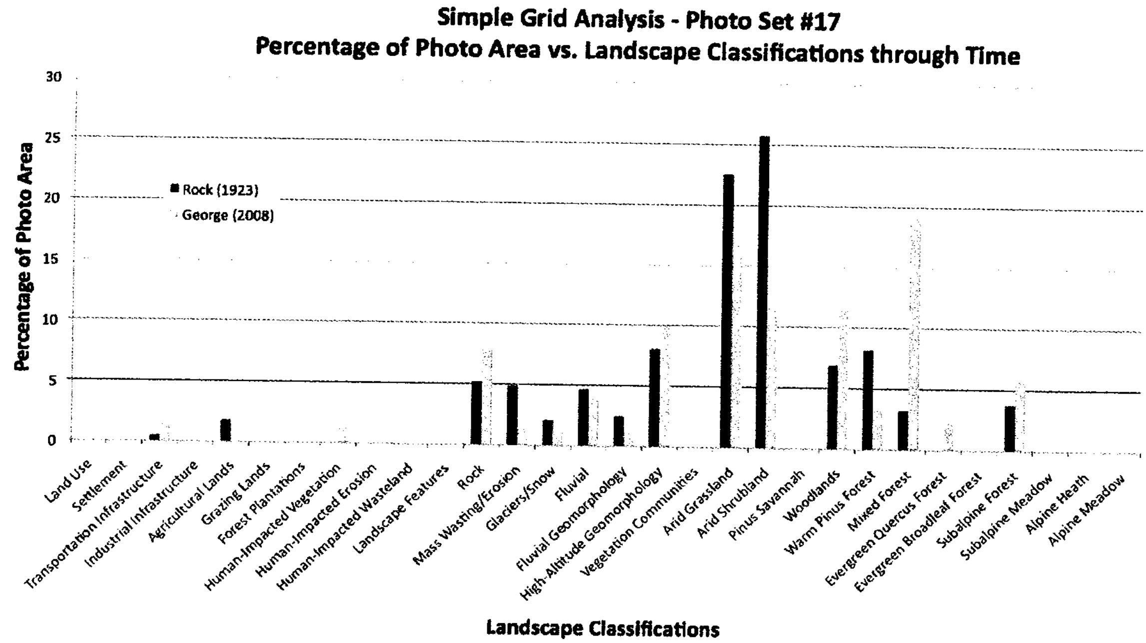


Table E.6 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #17

Photo Set # 17- Simple	Rock (1923)		George (2008)	
	Number	Percent	Number	Percent
[illegible]				
[illegible]	0	0.00	0	0.00
[illegible]	10	0.51	29	1.40
[illegible]	0	0.00	1	0.05
[illegible]	35	1.77	0	0.00
[illegible]	0	0.00	29	1.40
[illegible]				
[illegible]	103	5.22	163	7.87
[illegible]	97	4.91	28	1.35
[illegible]	41	2.08	24	1.16
[illegible]	92	4.66	80	3.87
[illegible]	49	2.48	23	1.11
[illegible]	159	8.06	206	9.95
[illegible]				
[illegible]	445	22.54	373	18.02
[illegible]	508	25.74	241	11.64
[illegible]	0	0.00	0	0.00
[illegible]	136	6.89	241	11.64
[illegible]	161	8.16	68	3.29
[illegible]	64	3.24	397	19.18
[illegible]	0	0.00	48	2.32
[illegible]	74	3.75	119	5.75
[illegible]	0	0.00	0	0.00

Figure E.8.1,2 Photo Set #19 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923) and George (2008).

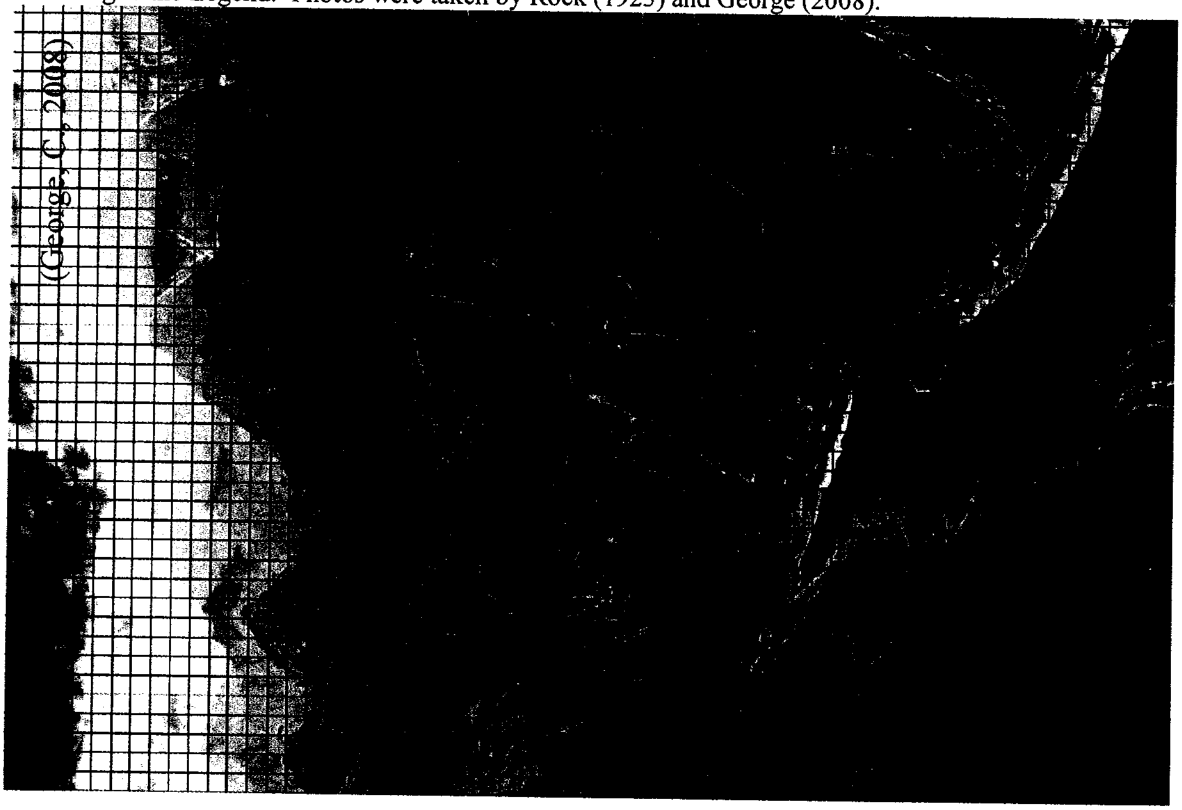


Figure E.8.3 The changing percentage photo area of each landscape classification through time.

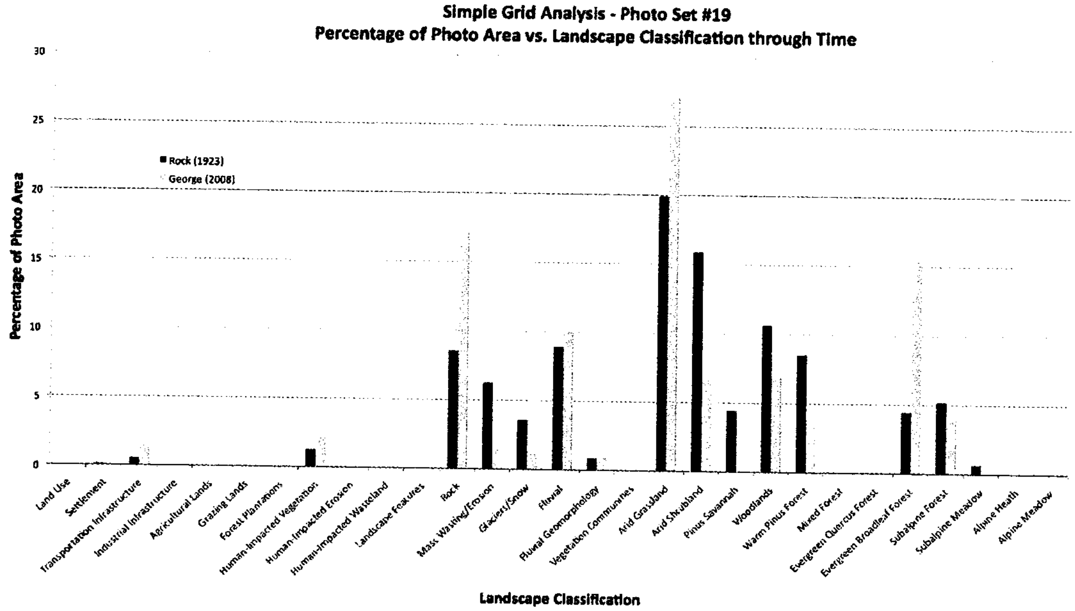
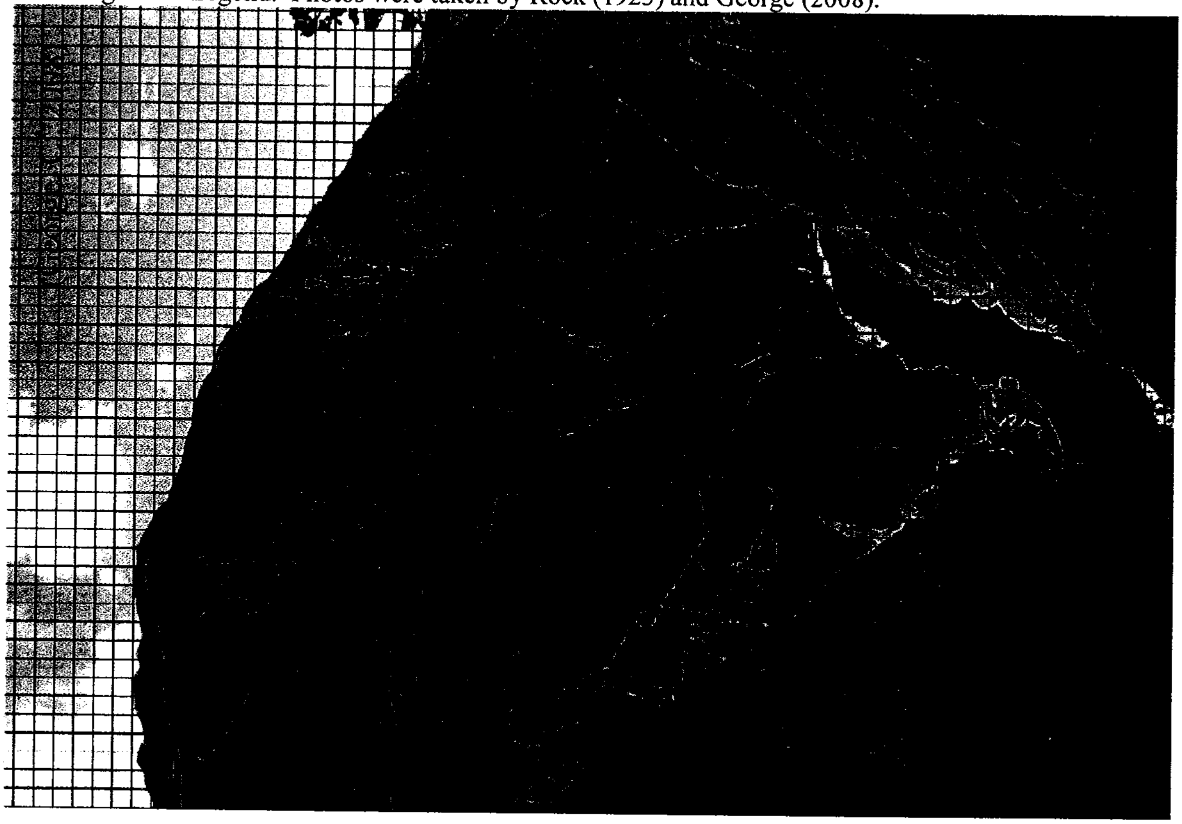


Table E.7 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #19

Photo Set # 19- Simple	Rock (1923)		George (2008)	
	Number	Percent	Number	Percent
[illegible]	2	0.19	7	0.42
[illegible]	9	0.53	25	1.50
[illegible]	0	0.00	9	0.54
[illegible]	22	1.30	36	2.15
[illegible]	145	8.58	286.5	17.14
[illegible]	106	6.27	26	1.56
[illegible]	61	3.61	20	1.20
[illegible]	151	8.94	168	10.05
[illegible]	15	0.89	15	0.90
[illegible]	337	19.94	456	27.27
[illegible]	269	15.92	117	7.00
[illegible]	75	4.44	0	0.00
[illegible]	180	10.65	117	7.00
[illegible]	144	8.52	65	3.89
[illegible]	75	4.44	257.5	15.40
[illegible]	88	5.21	67	4.01
[illegible]	11	0.65	0	0.00

Figure E.91,2. Photo Set #20 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923) and George (2008).



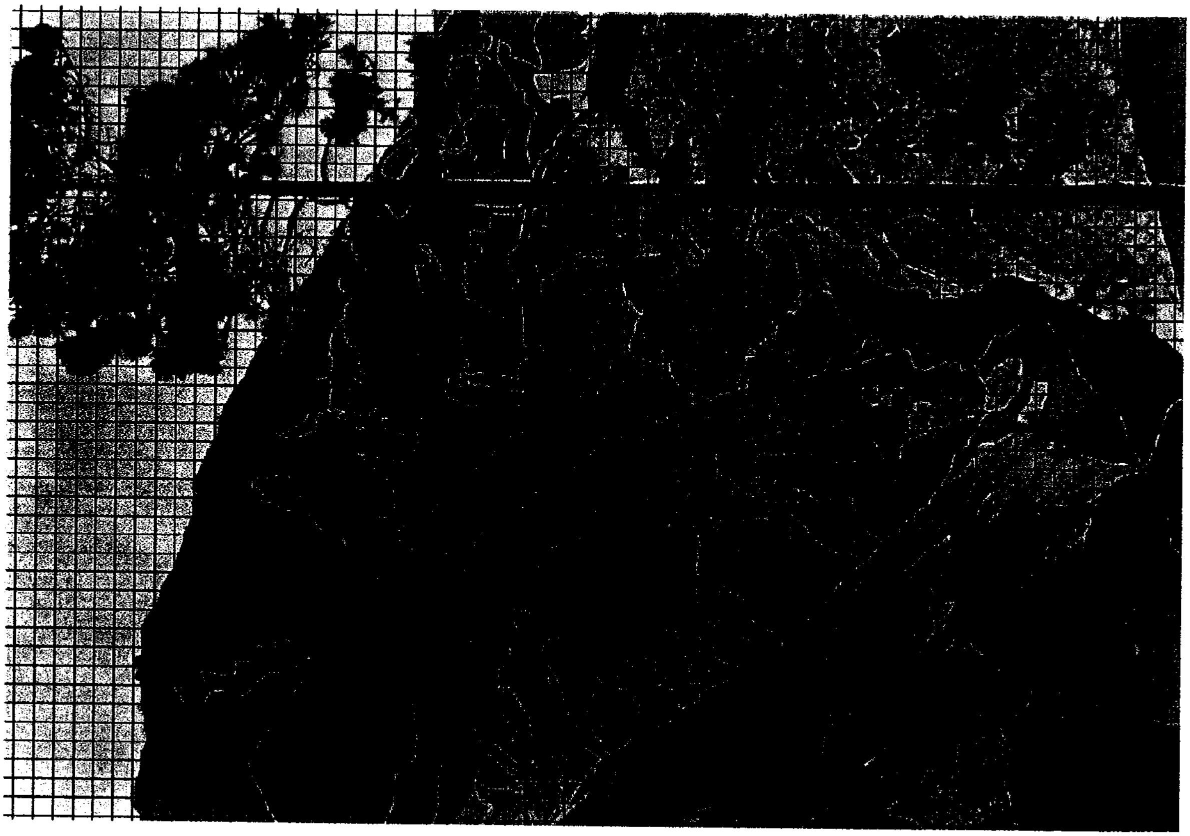


Figure E.9.3 The changing percentage photo area of each landscape classification through time.

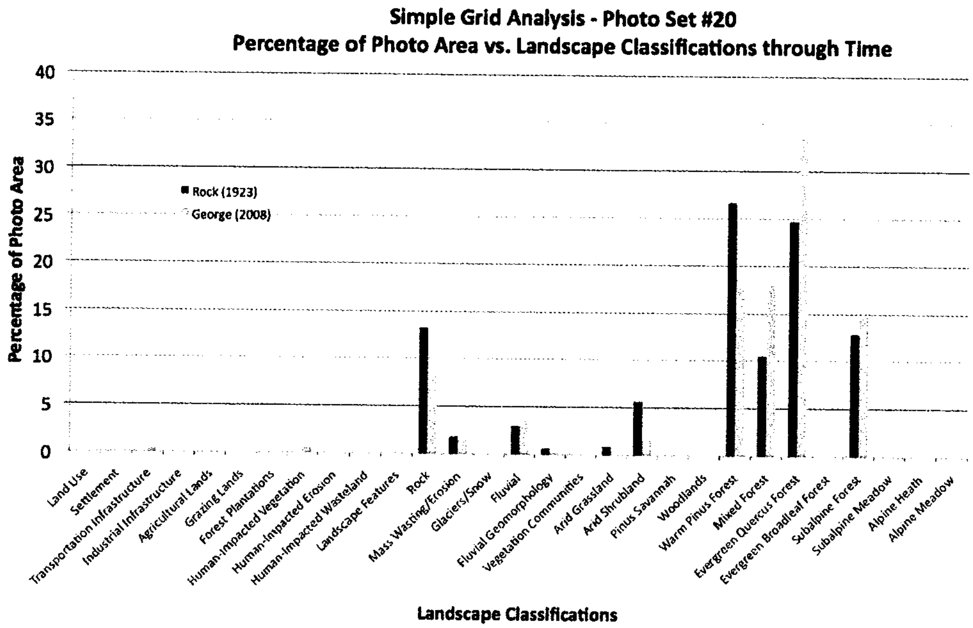


Table E.8 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #20

Photo Set # 20- Simple	Rock (1923)		George (2008)	
	Number	Percent	Number	Percent
	0	0.00	0	0.00
	0	0.00	6	0.32
	0	0.00	0	0.00
	0	0.00	10	0.53
	0	0.00	0	0.00
	0	0.00	0	0.00
	287	13.28	154	8.21
	39	1.80	28	1.49
	0	0.00	0	0.00
	65	3.01	69	3.68
	14	0.65	4	0.21
	18	0.83	0	0.00
	122	5.64	29	1.55
	0	0.00	0	0.00
	576	26.64	332	17.70
	228	10.55	340	18.12
	534	24.70	628	33.48
	279	12.91	276	14.71

Figure E.10.1,2 Photo Set #21 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923) and George (2008).

Figure E.10.3 The changing percentage photo area of each landscape classification through time.

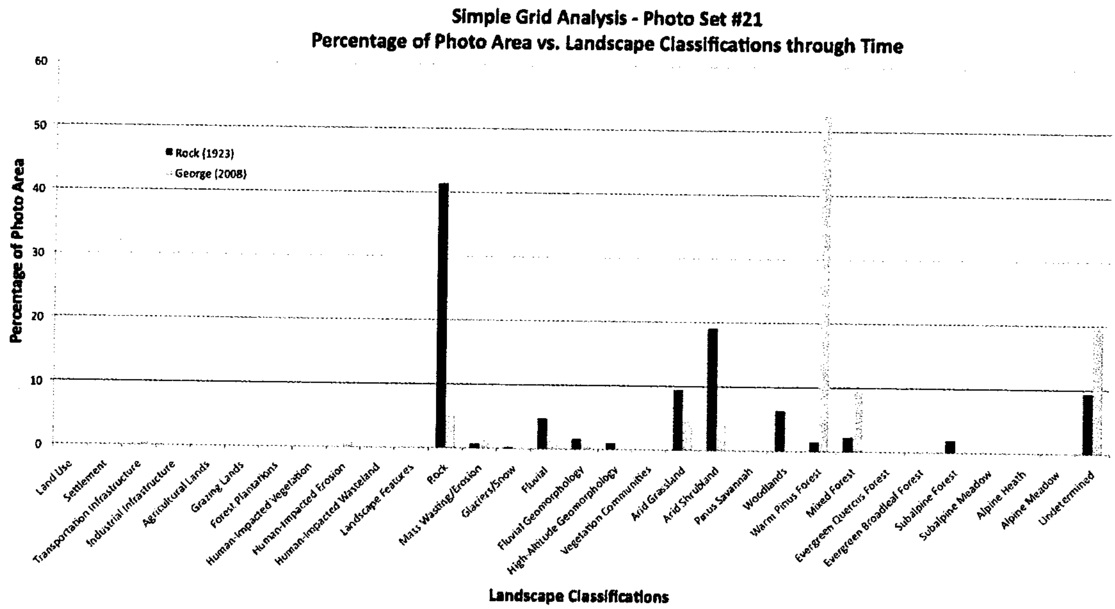


Table E.9 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #21

Photo Set # 21- Simple	Rock (1923)		George (2008)	
	Number	Percent	Number	Percent
[illegible]				
[illegible]	0	0.00	0	0.00
[illegible]	0	0.00	8	0.41
[illegible]	0	0.00	0	0.00
[illegible]	0	0.00	0	0.00
[illegible]	0	0.00	14	0.72
[illegible]	0	0.00	0	0.00
[illegible]				
[illegible]	550	41.45	97	5.00
[illegible]	10	0.75	24	1.24
[illegible]	3	0.23	0	0.00
[illegible]	64	4.82	26	1.34
[illegible]	22	1.66	12	0.62
[illegible]	13	0.98	0	0.00
[illegible]				
[illegible]	126	9.50	92	4.75
[illegible]	254	19.14	82	4.23
[illegible]	84	6.33	0	0.00
[illegible]	20	1.51	1016	52.45
[illegible]	30	2.26	183	9.45
[illegible]	26	1.96	0	0.00
[illegible]	125	9.42	383	19.77

Figure E.11.1,2 Photo Set #22 with a simple grid overlaid. Landscape characteristics are highlighted according to the Legend. Photos were taken by Rock (1923) and George (2008).

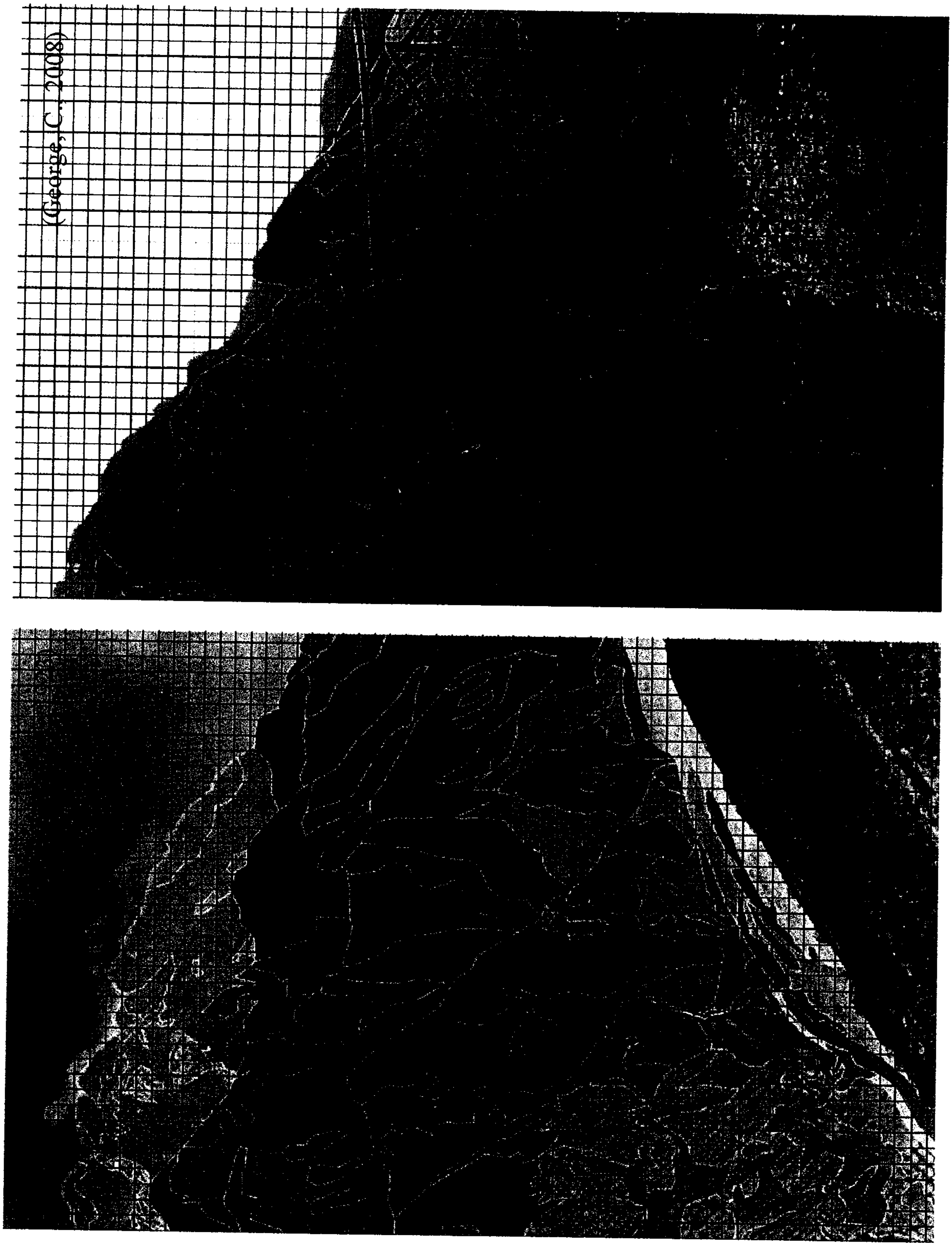


Figure E.11.3 The changing percentage photo area of each landscape classification through time.

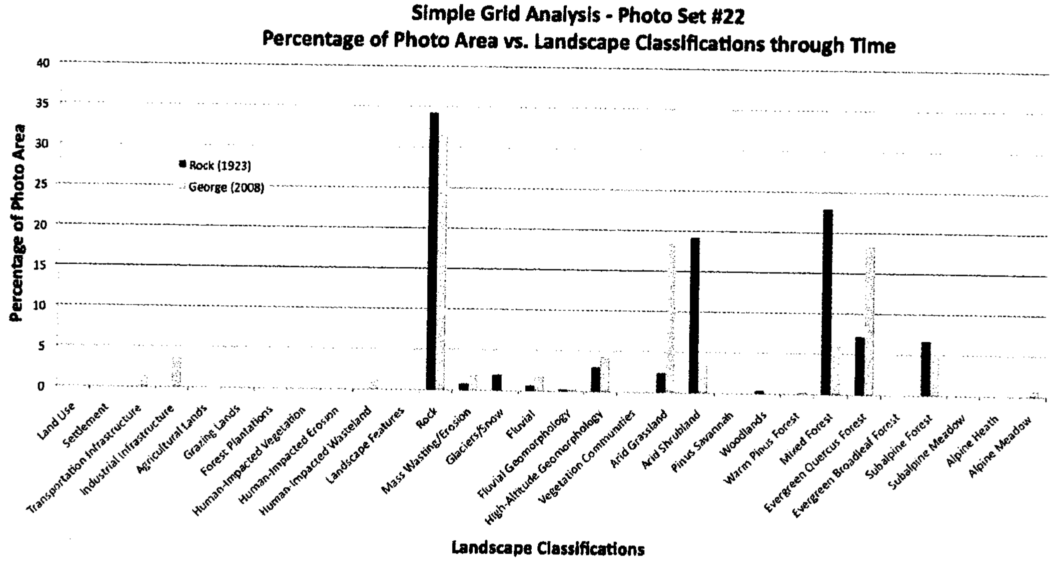


Table E.10 The number of squares occupied by each landscape classification, as well as the percentage photo area occupied by each landscape classification for each photo in Photo Set #22

Photo Set # 22- Simple	Rock (1923)		George (2008)	
	Number	Percent	Number	Percent
	0	0.00	0	0.00
	0	0.00	22	1.46
	0	0.00	57	3.78
	0	0.00	20	1.33
	562	34.27	475	31.52
	14	0.85	28	1.86
	33	2.01	0	0.00
	11	0.67	31	2.06
	4	0.24	8	0.53
	50	3.05	65	4.31
	40	2.44	283	18.78
	315	19.21	54	3.58
	0	0.00	0	0.00
	7	0.43	0	0.00
	0	0.00	7	0.46
	376	22.93	92	6.11
	118	7.20	276	18.32
	0	0.00	0	0.00
	110	6.71	78	5.18
	0	0.00	11	0.73

APPENDIX F:
PHOTO INTERPRETATION
SCALED GRID ANALYSIS

This appendix offers a reader a chance to look at the photographs that have been quantitatively analyzed using Scaled Grid Analysis. This method is based on the use of grid planes calibrated to fit the topography of the landscape. Each grid plane is scaled based on the distance from the photo point to each landscape feature. Three photo sets - #3, #14, and #16 - where analyzed using this methodology. In this appendix, each of the steps are shown.

First, I used Google Earth to establish the coordinates of different layers in the photograph (latitude and longitude in degrees, minutes, seconds, and altitude in meters above sea level). I then used trigonometry to calculate the distance between each layer and the photo point.

First, I calculated the horizontal distance from the photo point to the plane using the following formula:

$$\Delta D_h = ACOS(SIN(Lat1) * SIN(Lat2) + COS(Lat1) * COS(Lat2) * COS(Lon2 - Lon1)) * 6371$$

Once I had the horizontal distance calculated, I found the distance from my photo points to each layer by factoring in the difference in altitude between the two points using the following equation:

$$\Delta D_v = (Alt1) - (Alt2)$$

$$D = \sqrt{(\Delta D_h)^2 + (\Delta D_v)^2}$$

Where ΔD_h is the horizontal distance between points, calculated by latitude and longitude coordinates and ΔD_v is the vertical distance, calculated by determining the difference between altitude points.

Using the calculated distances (D), I determined a ratio for grid size. I did this by determining an appropriate grid size for the center layer and then adjusting the grid size of each layer using a simple ratio:

$$S_1 * D_1 = S_2 * D_2$$

$$S_2 = \frac{S_1 * D_1}{D_2}$$

S is the length of a grid side, and D is the distance from the layer's plane to the photo point.

This appendix provides the photographs with the scaled grid overlaid, as well as tables showing the value of each landscape classification through total number of squares and percentage area occupied by each landscape classification. Each landscape classification is represented on the photographs according to the legend (**Figure F.1**).

Figure F.1 The legend for the colour-coded landscape classifications.

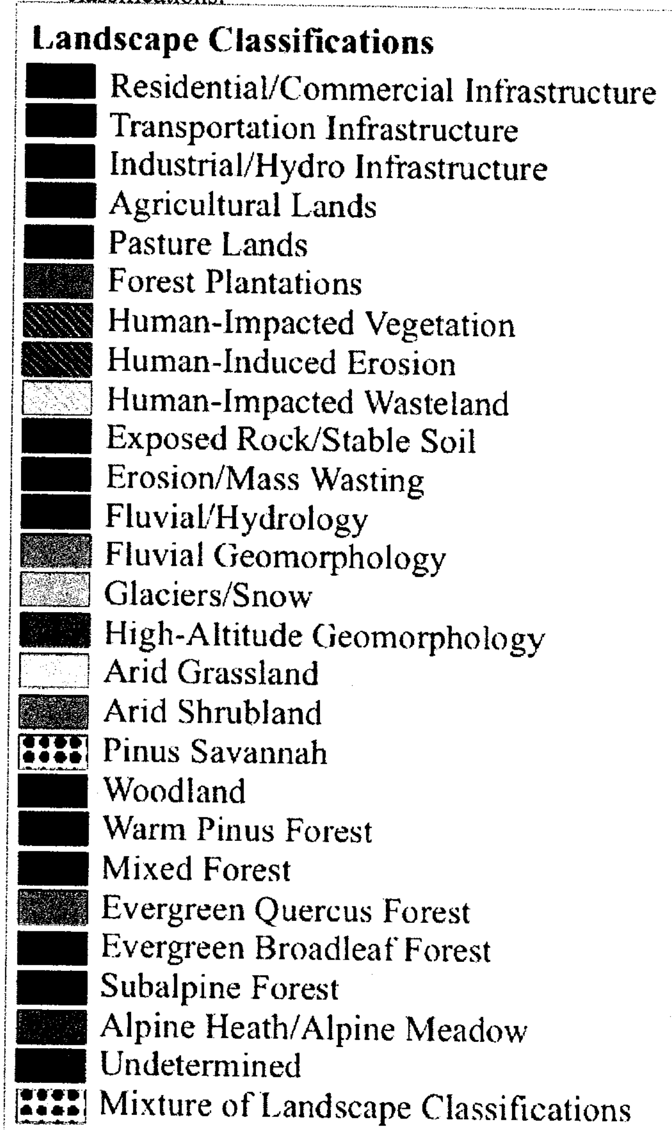


Photo Set #3

Figure F.2.1 The latitude, longitude and altitude points used to calculate the distance from each landscape feature to the photo point in Photo Set #3. This image and the coordinates were taken from Google Earth.

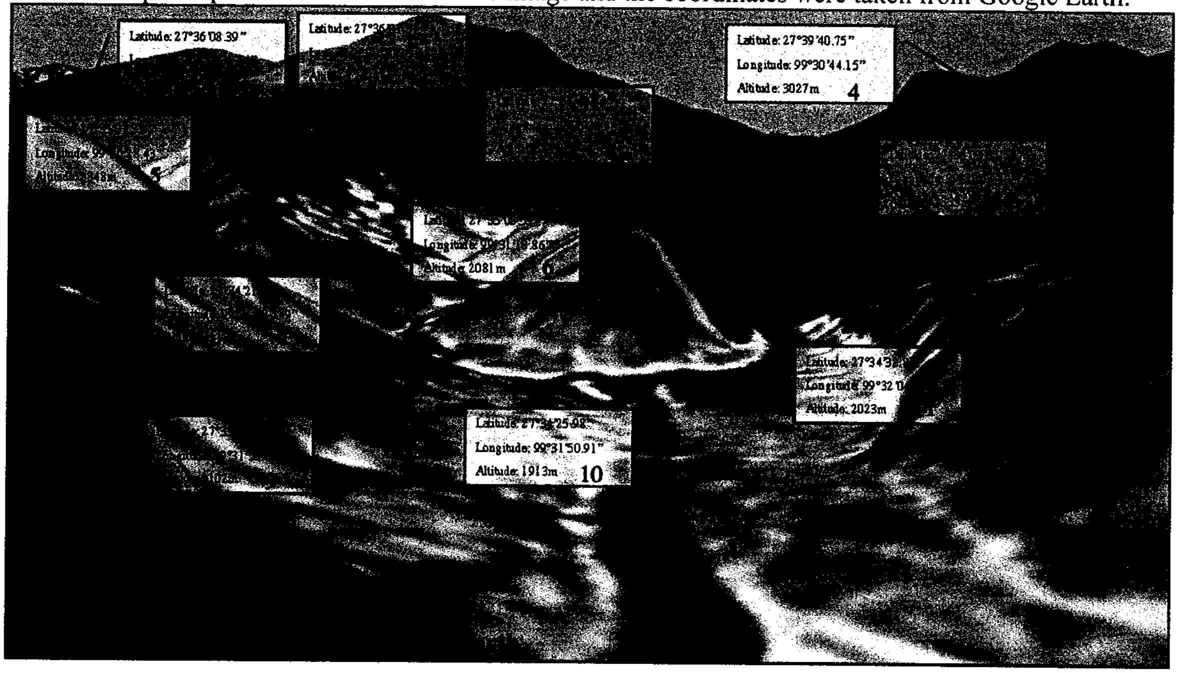
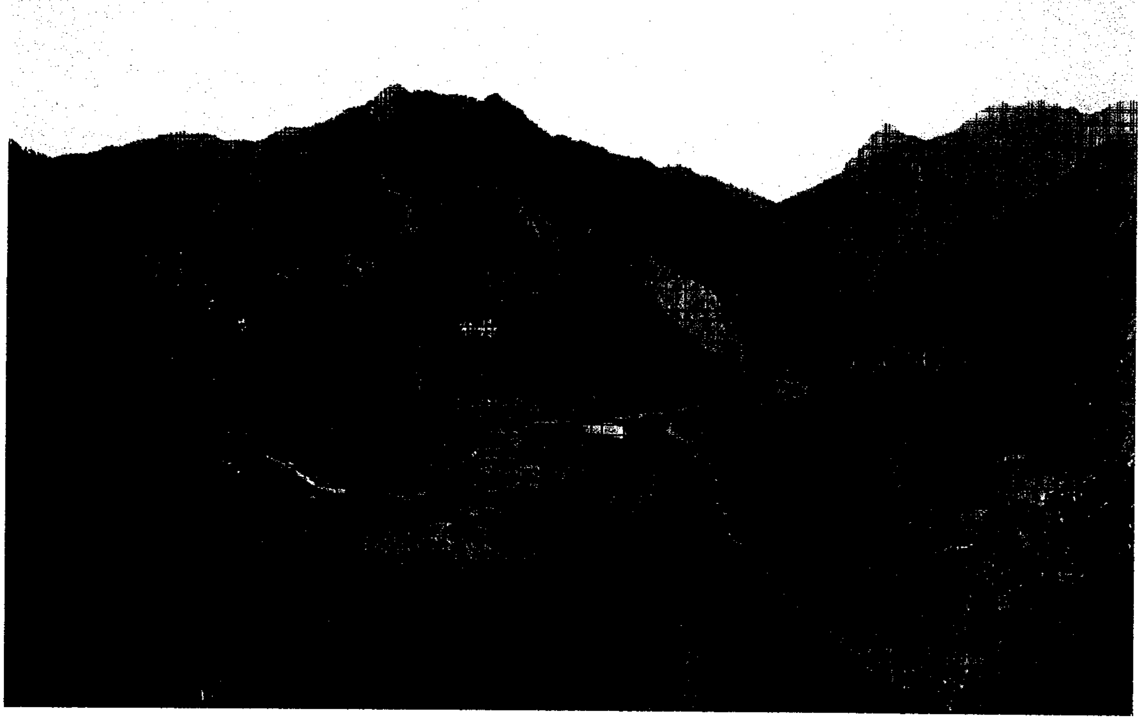
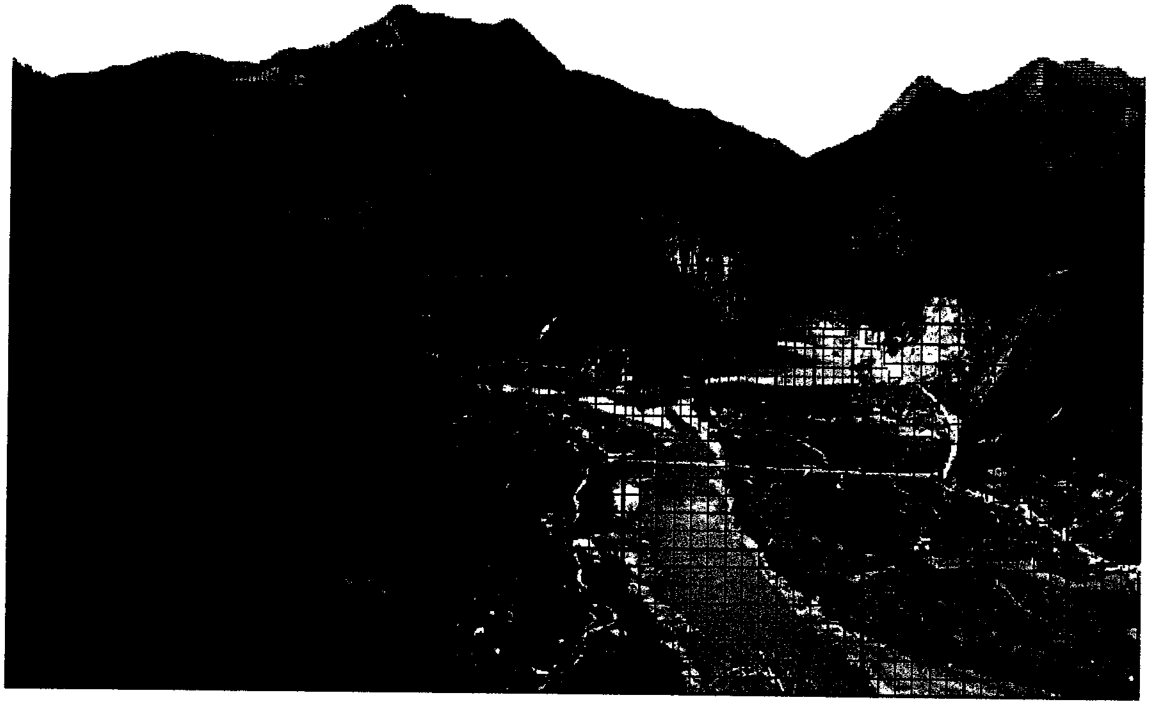


Figure F.2.2-4 Photo Set #3 equipped with scaled grids that have been calibrated to fit the landscape through calculating the distance from each landscape feature to the photo point and using a simple ratio to calculate the appropriate grid size.

(Rock, J. 1923)



(Moseley, R. 2003)



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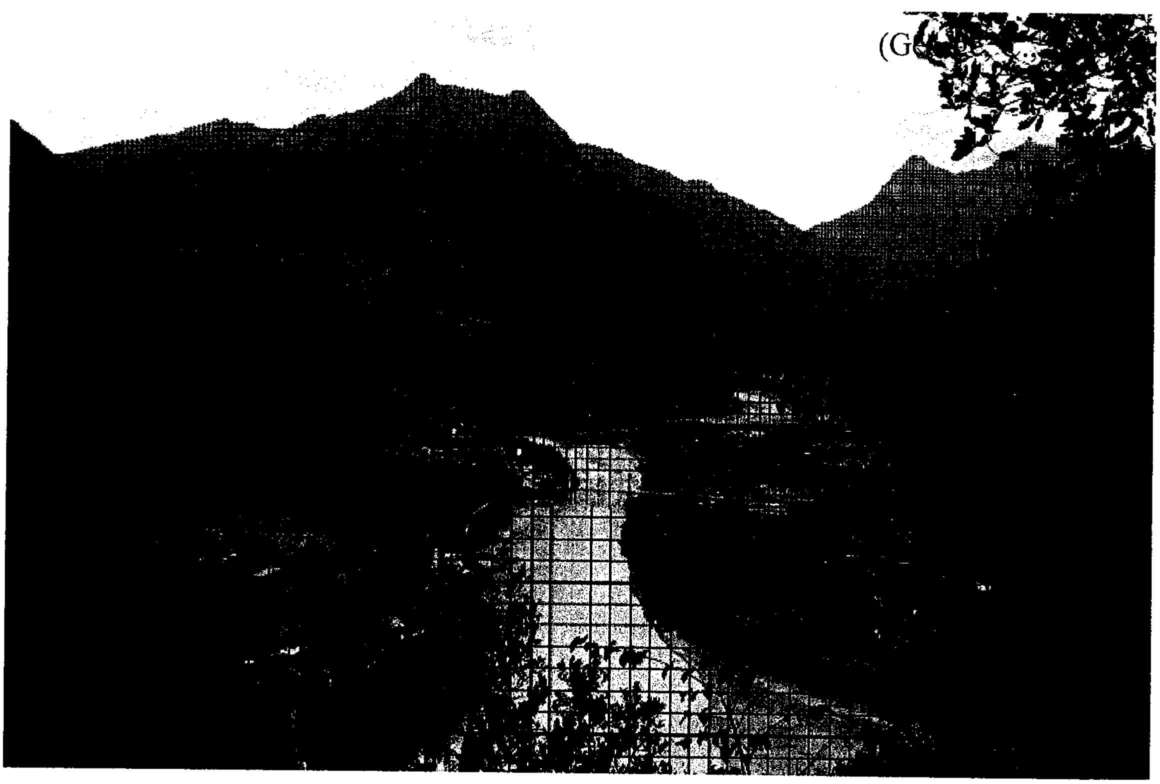
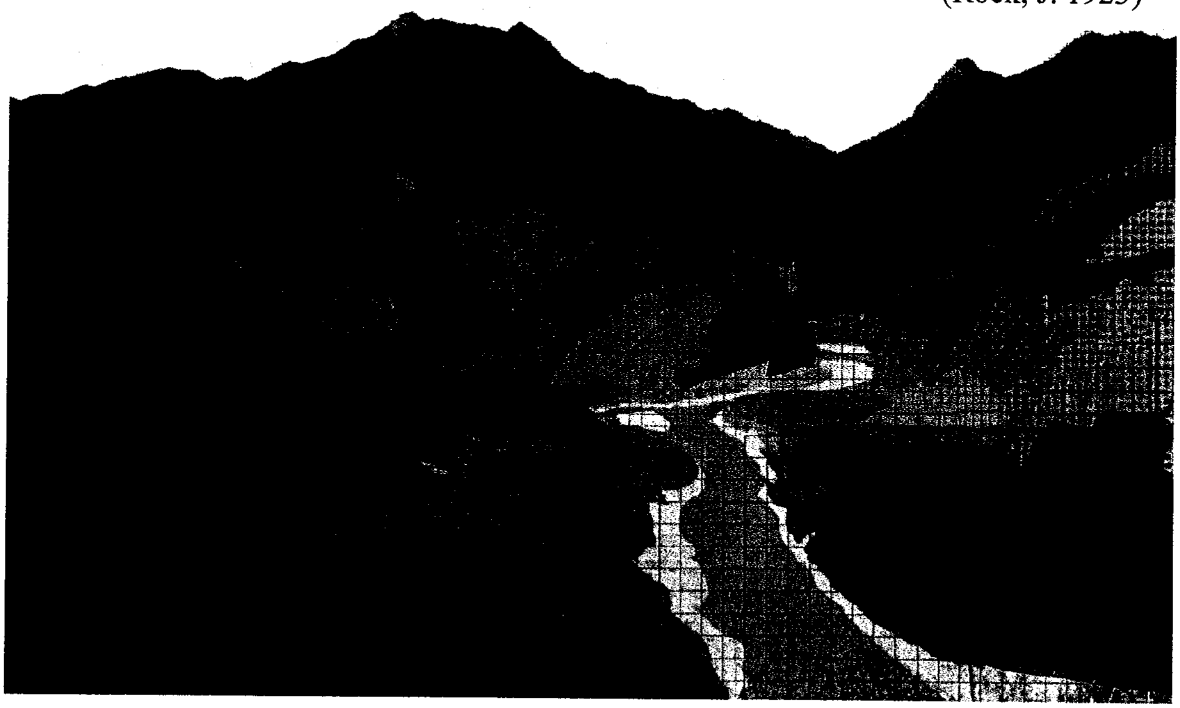
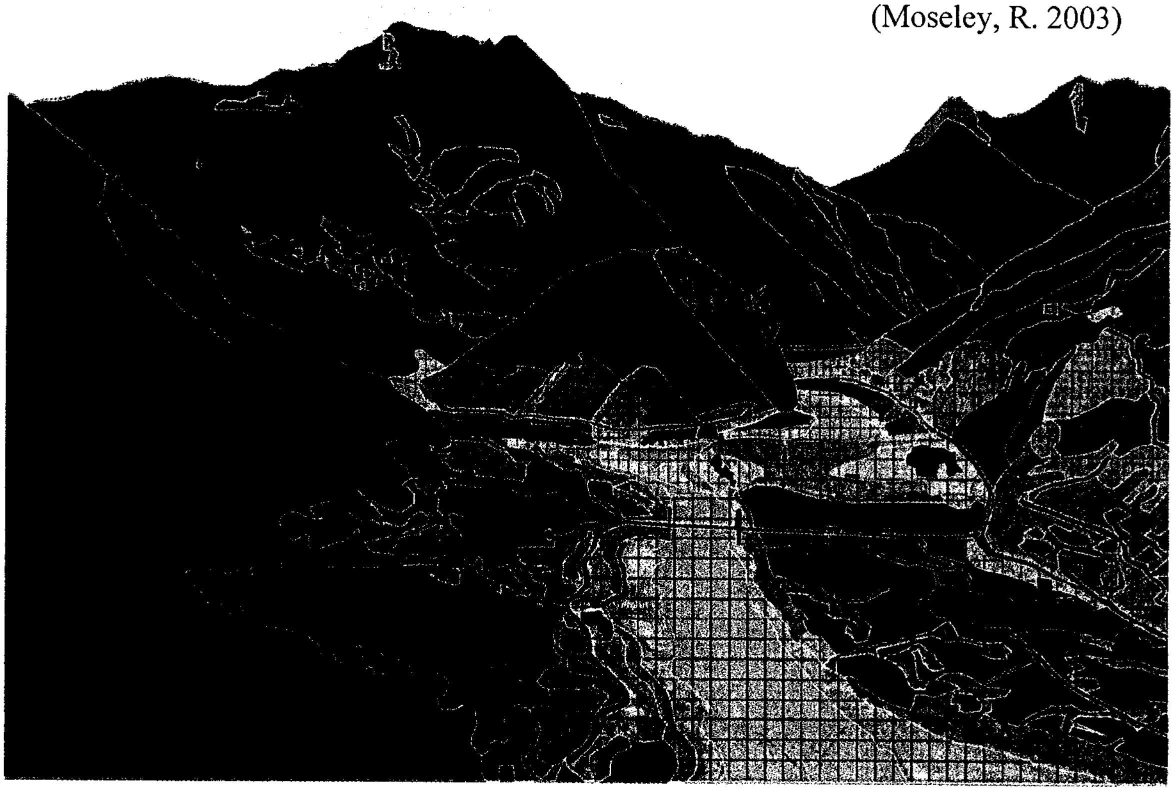


Figure F.2.5-7 Photo Set #3 with scaled grids overlaid that are calibrated to fit the landscape. Also, the colour-coded distributions of vegetation communities have been added to calculate the spatial changes to landscape characteristics.

(Rock, J. 1923)



(Moseley, R. 2003)



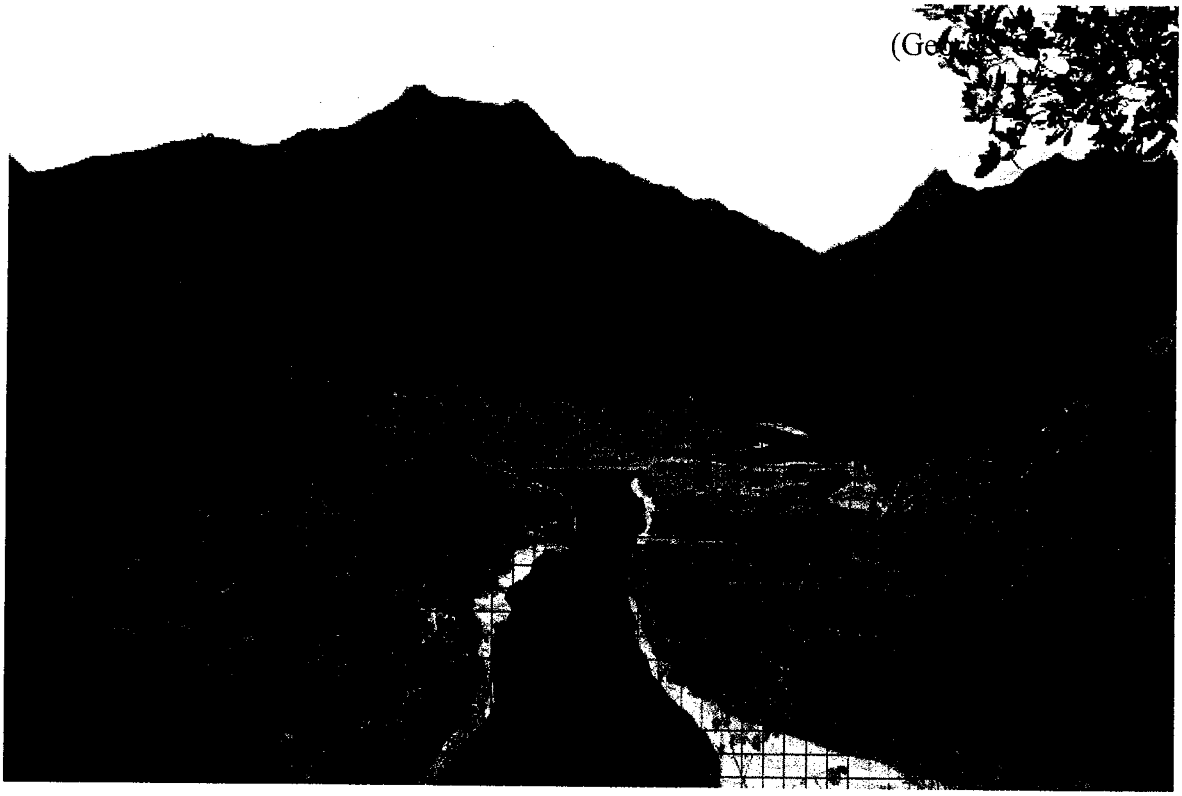


Figure F.2.8 A graph showing the percentage of landscape area versus the different landscape classifications through time. The values were determined by using Scaled Grid Analysis. The photographs were taken by Rock (1923), Moseley (2003), and George (2008).

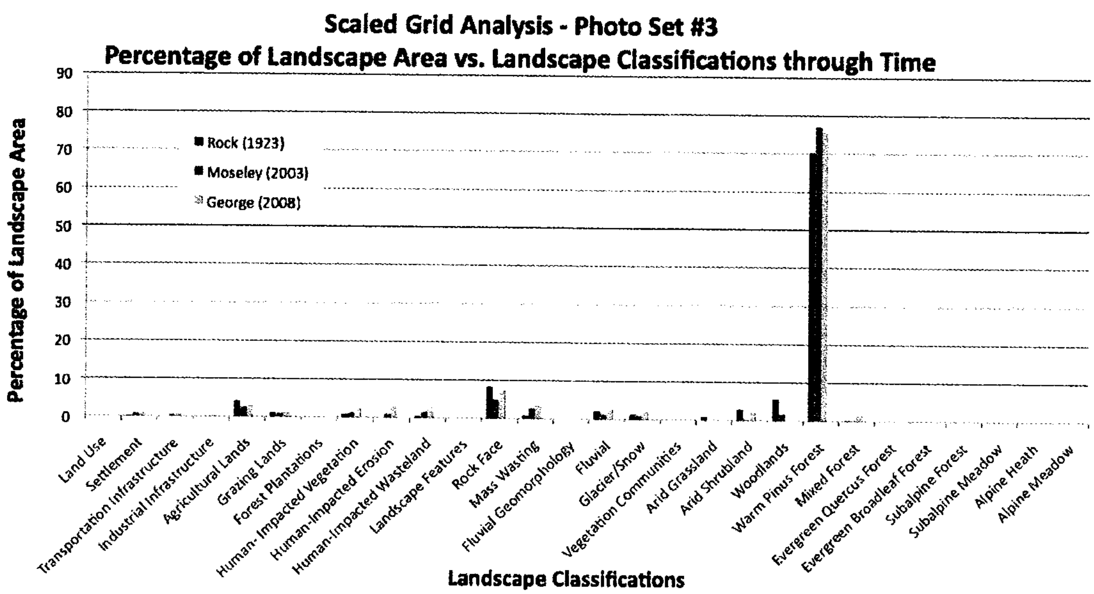


Table F.1 This table shows the number values calculated using Scaled Grid Analysis for Photo Set #3. The first column shows the number of squares occupied by each landscape classification in each photograph (Rock, Moseley, George). The number values are calculated into percentages of the total number of squares in each photograph.

Photo Set #3 - Scaled	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
Settlement	18	0.26	73	0.78	68	1.05
Transportation Infrastructure	0	0.00	50	0.54	41	0.64
Industrial Infrastructure	0	0.00	5	0.05	12	0.19
Agricultural Lands	295	4.31	244	2.62	195	3.02
Grazing Lands	87	1.27	97	1.04	77	1.19
Human Impacted Vegetation	60	0.88	127	1.36	164	2.54
Human Impacted Erosion	0	0.00	95	1.02	194	3.01
Human Impacted Wasteland	33	0.48	155	1.66	185	2.87
Rock Face	577	8.43	475	5.09	492	7.62
Mass Wasting	59	0.86	267	2.86	234	3.63
Fluvial	147	2.15	126	1.35	184	2.85
Pluvial Geomorphology	95	1.39	96	1.03	134	2.08
Arid Grassland	63	0.92	0	0.00	0	0.00
Arid Shrubland	202	2.95	30	0.32	131	2.03
Woodlands	385.5	5.63	161	1.73	0	0.00
Warm *Pinus* Forest	4810.5	70.29	7188	77.05	4890	75.74
Mixed Forest	12	0.16	29	0.31	108	1.67
[illegible]	[illegible]	[illegible]	[illegible]	100.00	[illegible]	[illegible]

Photo Set #14

Figure F.3.1 The latitude, longitude and altitude points used to calculate the distance from each landscape feature to the photo point in Photo Set #14. This image and the coordinates were taken from Google Earth.

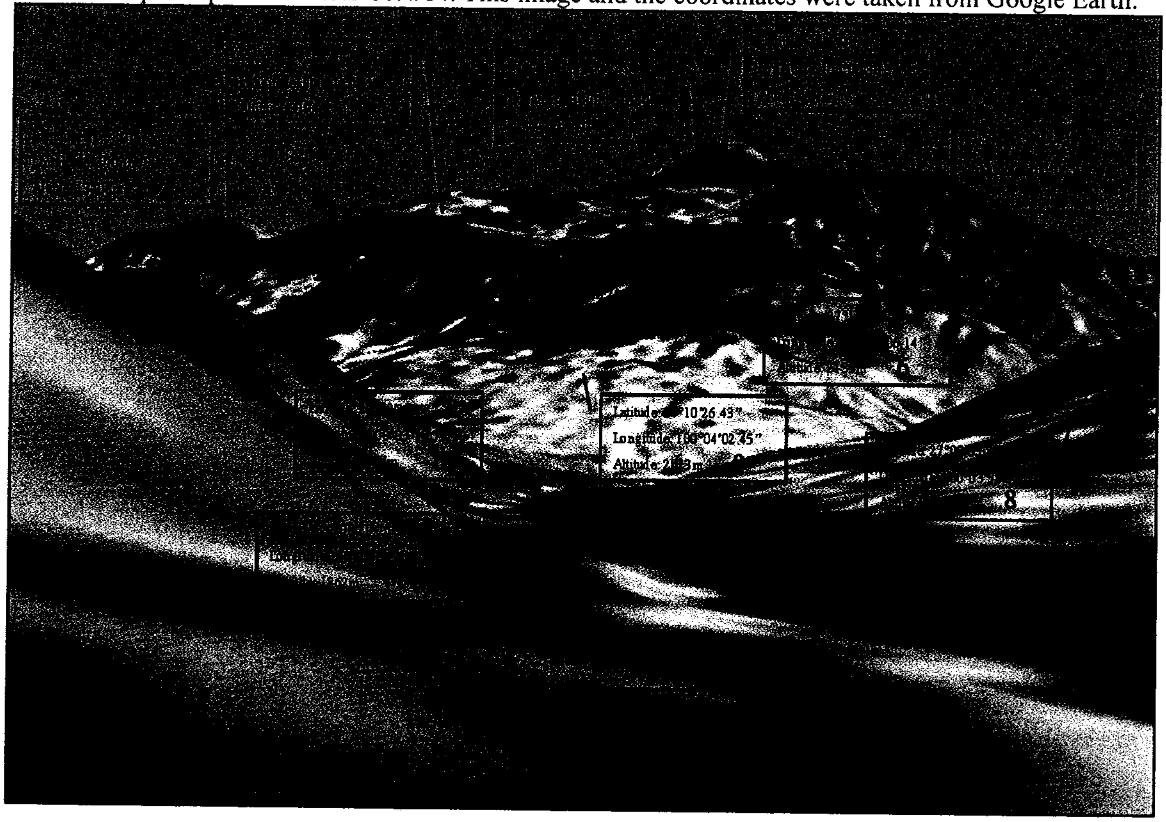
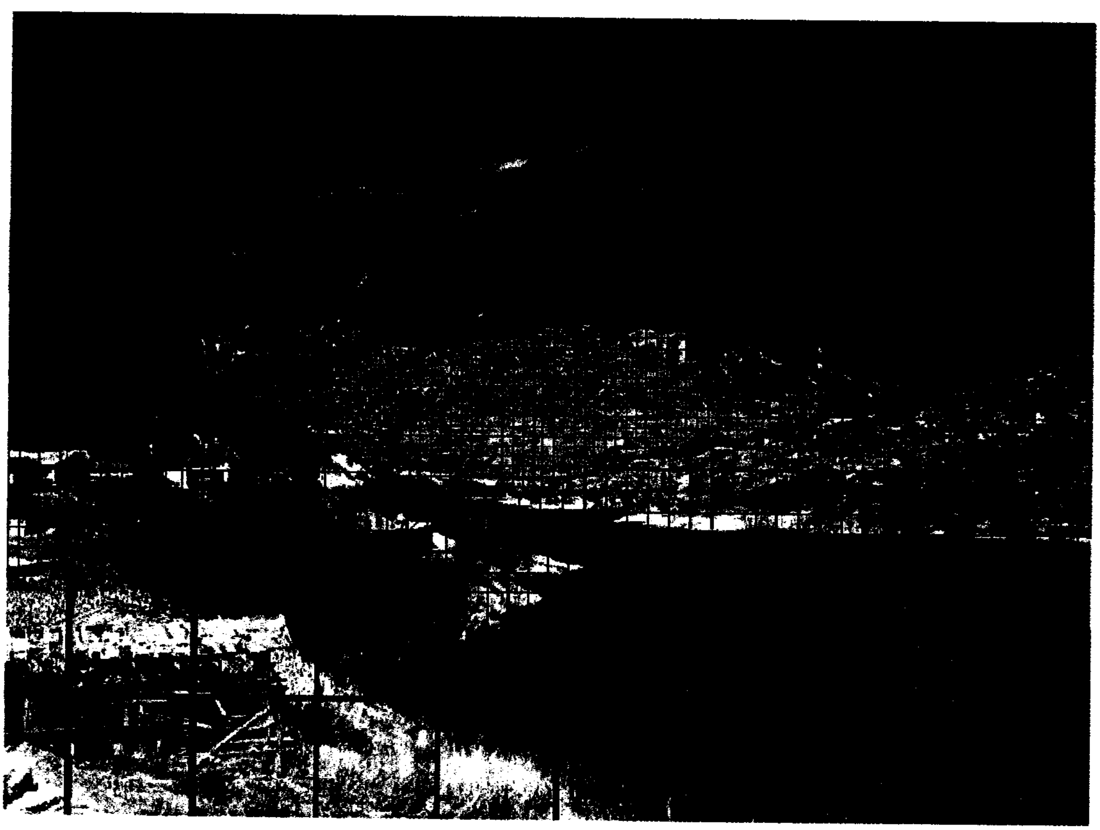


Figure F.3.2-4 Photo Set #14 equipped with scaled grids that have been calibrated to fit the landscape through calculating the distance from each landscape feature to the photo point and using a simple ratio to calculate the appropriate grid size.



(George, C., 2008)

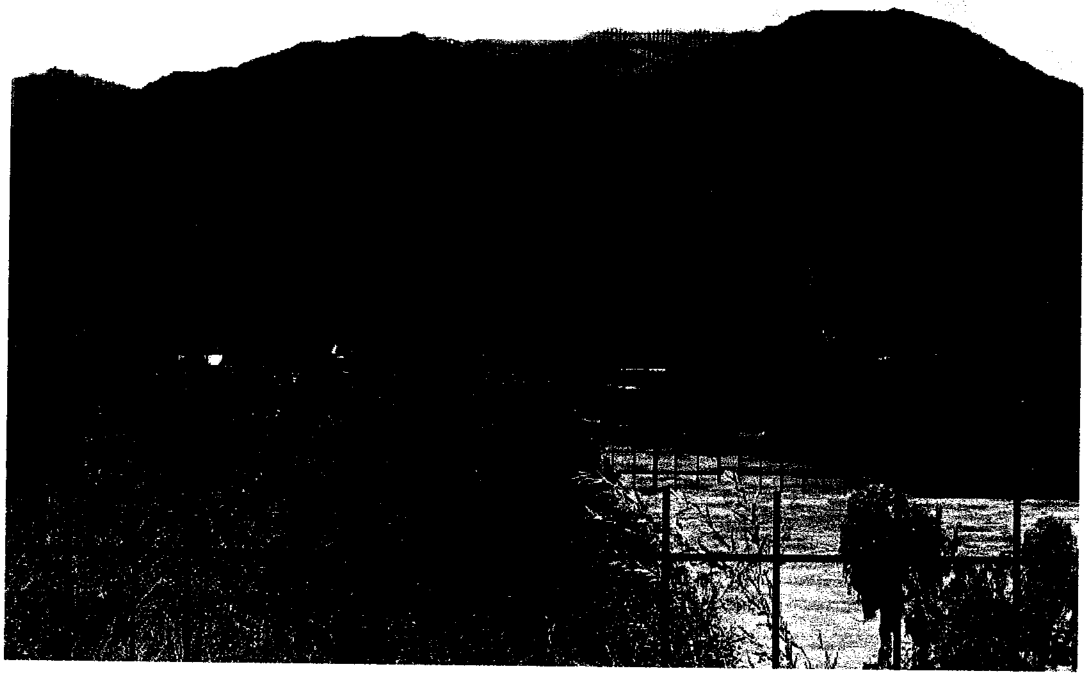
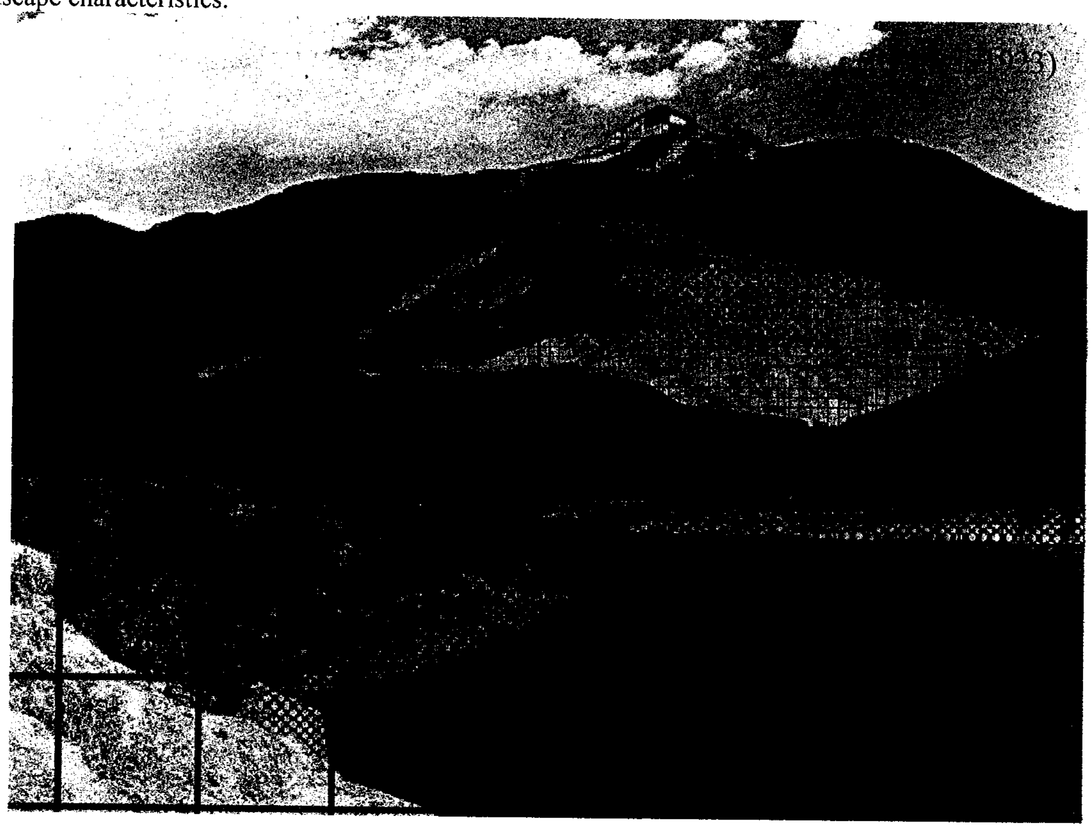
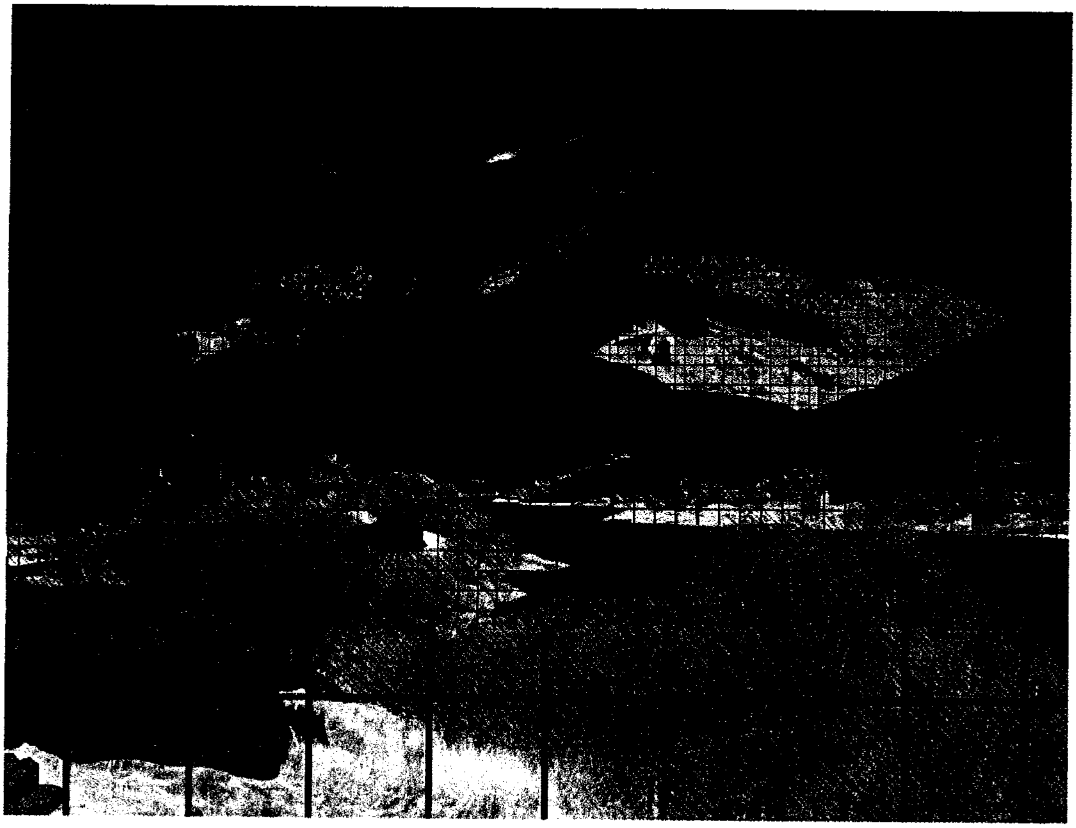


Figure F.3.5-7 Photo Set #14 with scaled grids overlaid that are calibrated to fit the landscape. Also, the colour-coded distributions of vegetation communities have been added to calculate the spatial changes to landscape characteristics.





(George, C., 2008)

Figure F.3.8 A graph showing the percentage of landscape area versus the different landscape classifications through time. The values were determined by using Scaled Grid Analysis. The photographs were taken by Rock (1923), Moseley (2003), and George (2008).

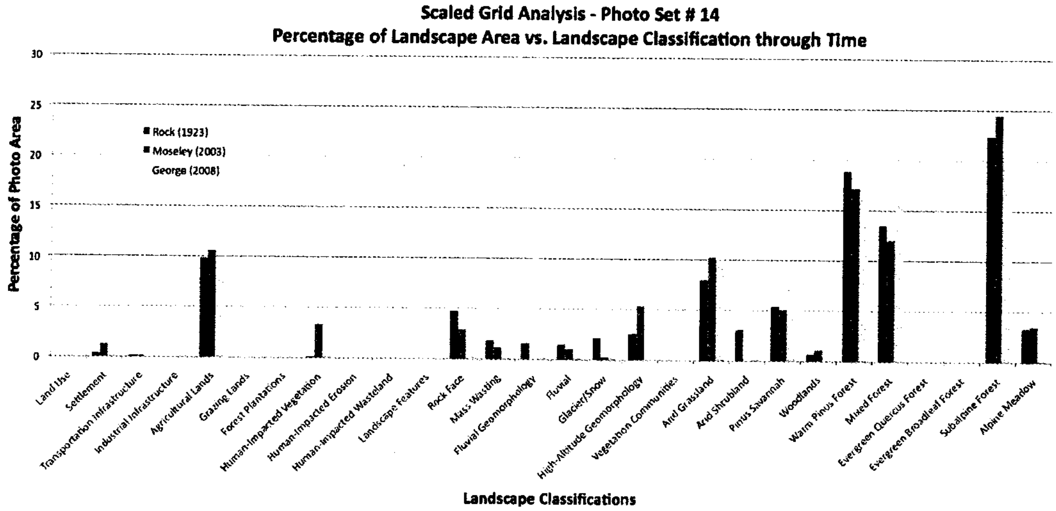


Table F.2 This table shows the empirical results of the scaled grid analysis of Photo Set #14. The first column shows the number of squares occupied by each landscape classification in each photograph (Rock, Moseley, George). The number values are calculated into percentages of the total number of squares in each photograph.

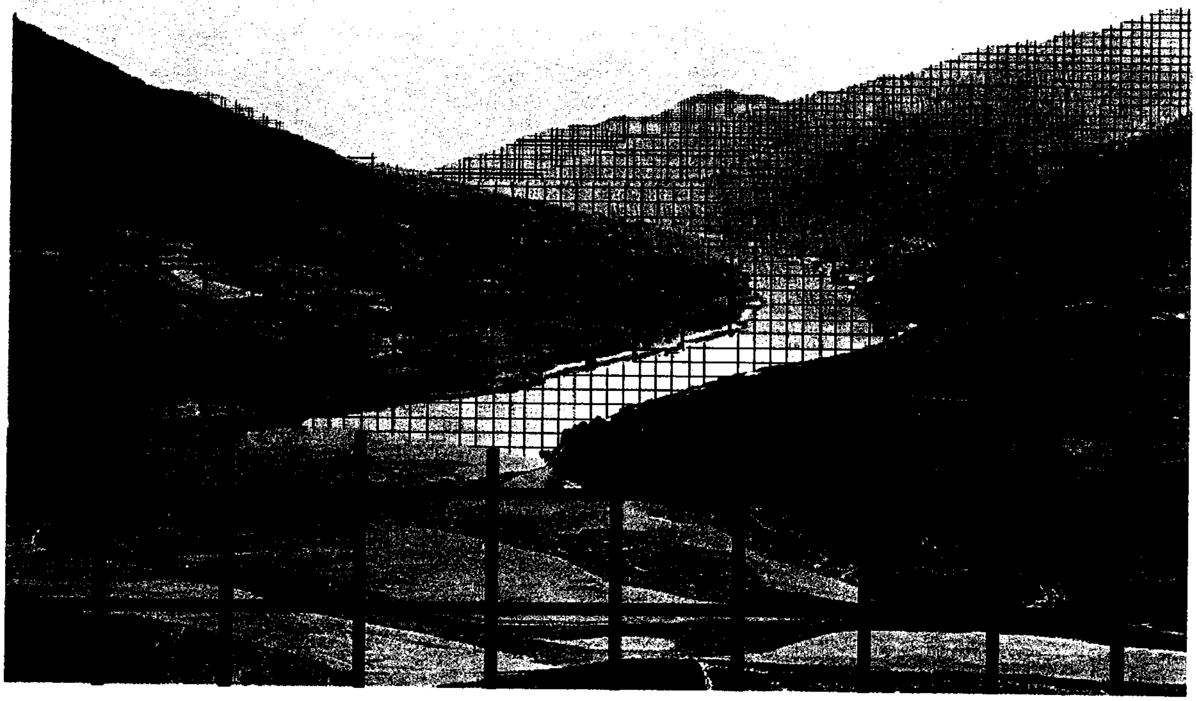
Photo Set #14 - Scaled	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
Settlement	18	0.37	64	1.26	56	0.95
Transportation Infrastructure	5	0.10	8	0.16	4	0.07
Industrial Infrastructure	0	0.00	1	0.02	10	0.17
Agricultural Lands	477	9.87	540	10.61	549	9.30
Human Impacted Vegetation	4	0.08	171	3.36	156	2.64
Rock Face	229	4.74	150	2.95	113	1.91
Mass Wasting	89	1.841	60	1.18	72	1.22
Eluvial Geomorphology	76	1.57	0	0.00	101	1.71
Fluvial	72	1.49	55	1.08	63	1.07
Glacier/Snow	105	2.17	14	0.28	5	0.09
High Altitude Geomorphology	125	2.59	272	5.34	0	0.00
Arid Grassland	386	7.98	522	10.26	587	9.94
Arid Shrubland	148	3.06	0	0.00	77	1.30
Trees Savannah	261	5.40	261	5.13	435	7.37
Woodlands	32	0.67	58	1.14	59	1.00
Warm Pine Forest	912	18.86	875	17.19	1119	18.95
Mixed Forest	653	13.51	613	12.04	976	16.53
Subalpine Forest	1083	22.40	1247	24.50	1333	22.57
Alpine Meadow	160	3.31	179	3.52	190	3.22
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Photo Set #16

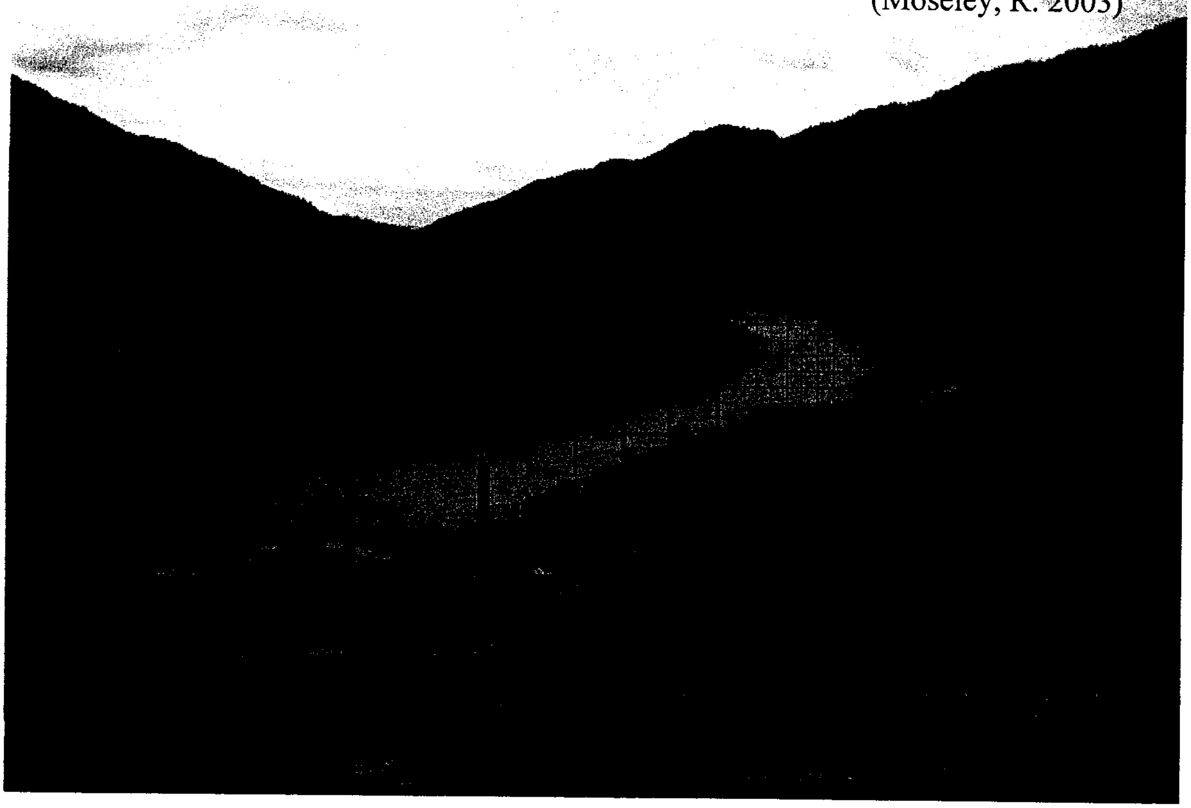
Figure F.4.1 The latitude, longitude and altitude points used to calculate the distance from each landscape feature to the photo point in Photo Set #16. This image and the coordinates were taken from Google Earth.

Figure F.4.2-4 Photo Set #16 equipped with the scaled grids that have been calibrated to fit the landscape through calculating the distance from each landscape feature to the photo point and using a simple ratio to calculate the appropriate grid size.

(Rock, J. 1923)



(Moseley, R. 2003)



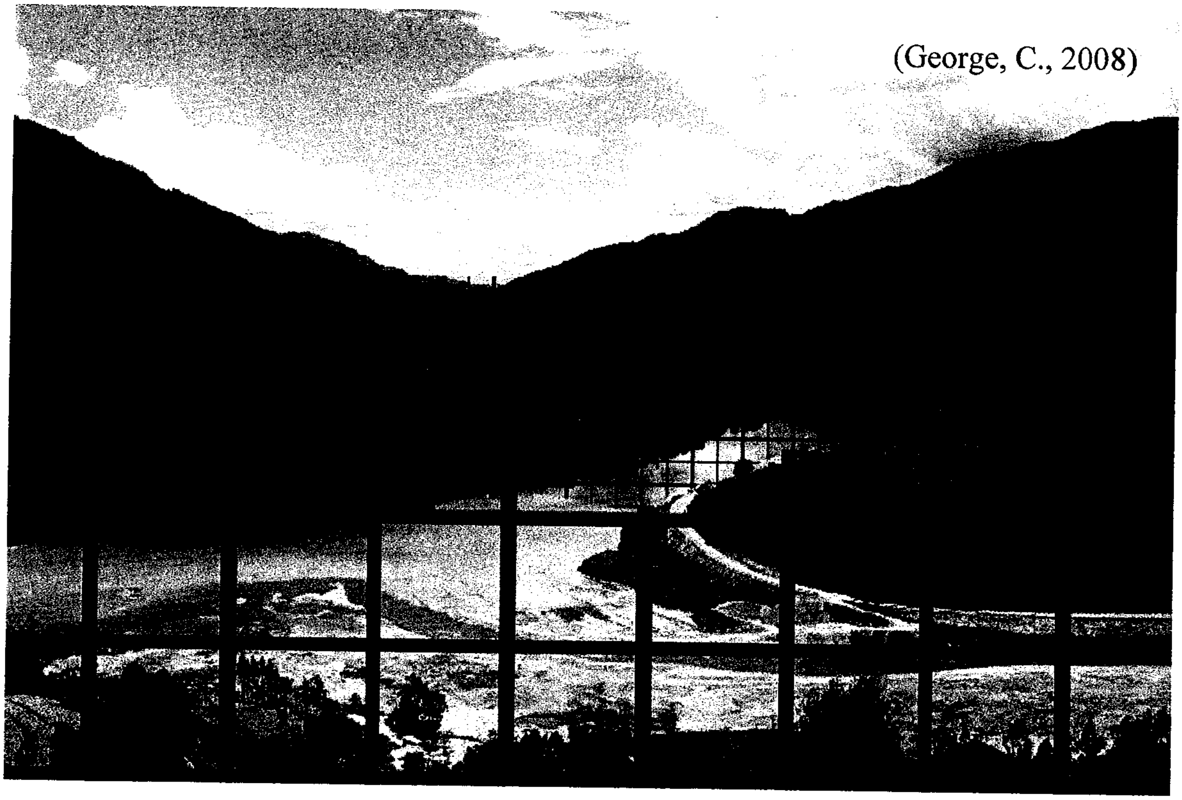
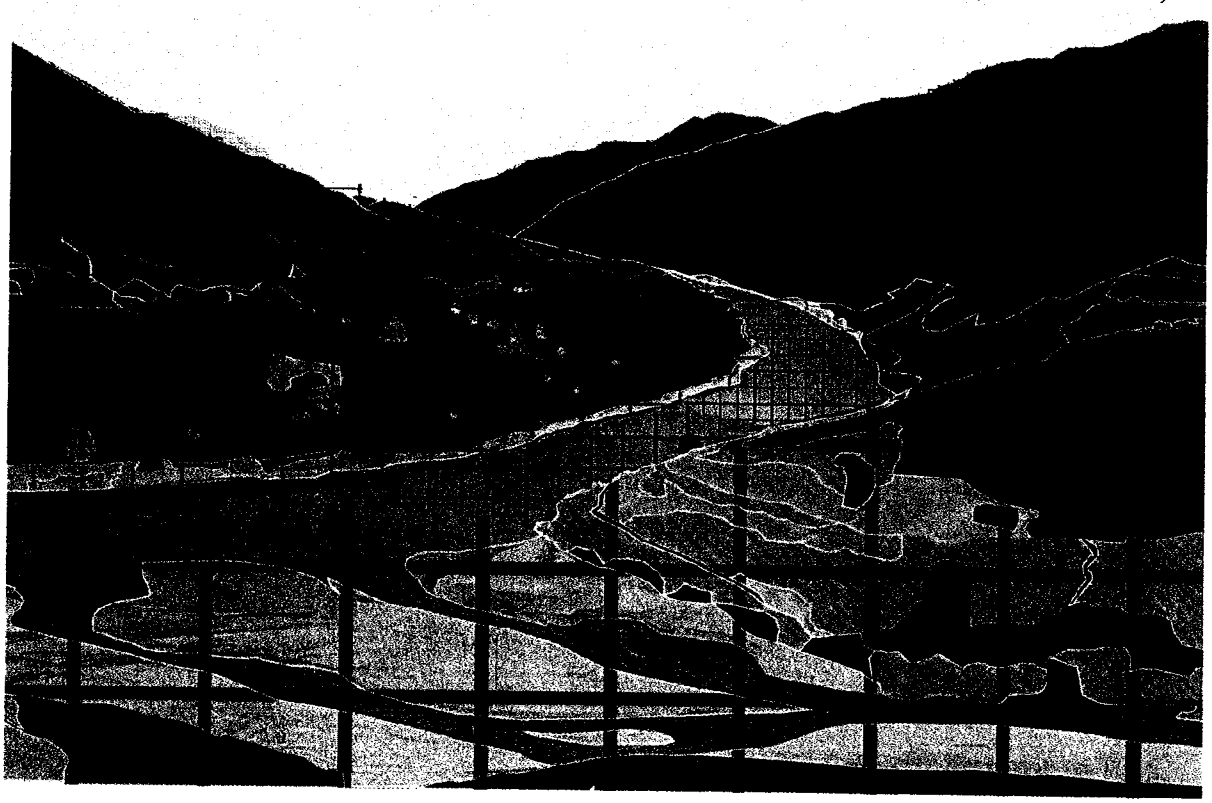
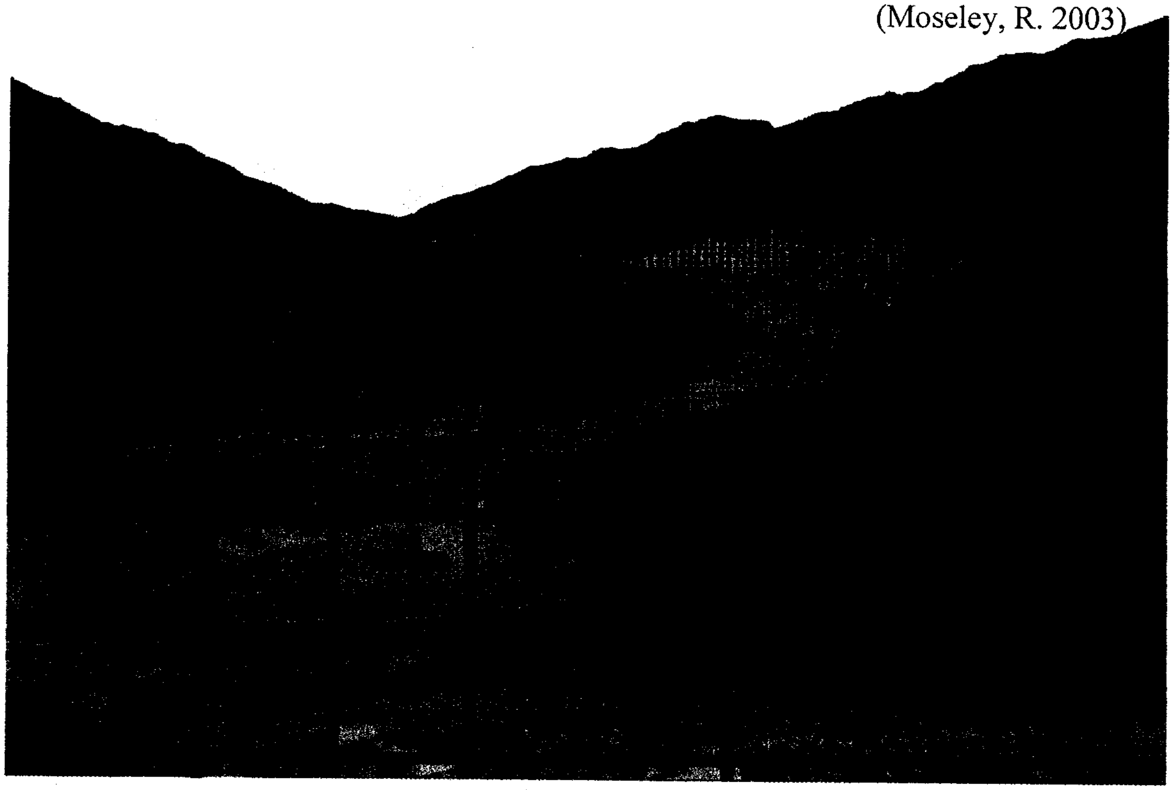


Figure F.4.5-7 Photo Set #16 with scaled grids overlaid that are calibrated to fit the landscape. Also, the colour-coded distributions of vegetation communities have been added to calculate the spatial changes to landscape characteristics.

(Rock, J. 1923)



(Moseley, R. 2003)



(George, C., 2008)

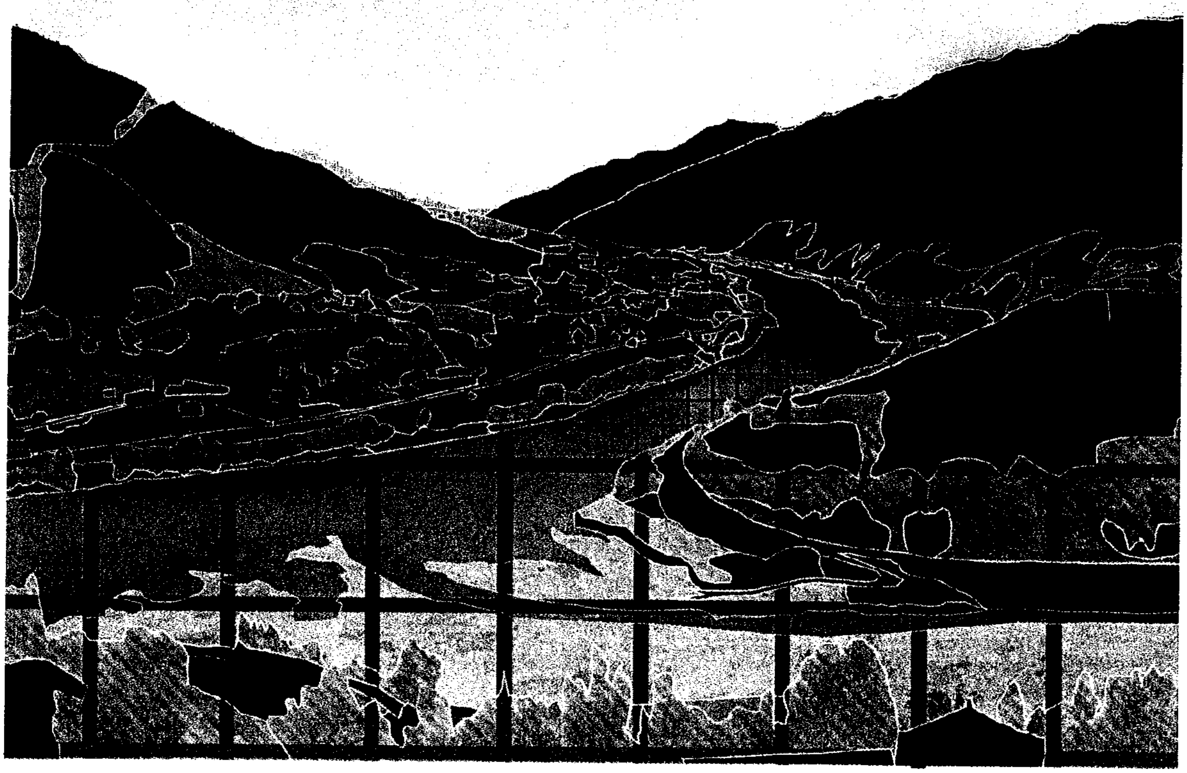


Figure F.4.8 A graph showing the percentage of landscape area versus the different landscape classifications through time. The values were determined by using Scaled Grid Analysis. The photographs were taken by Rock (1923), Moseley (2003), and George (2008).

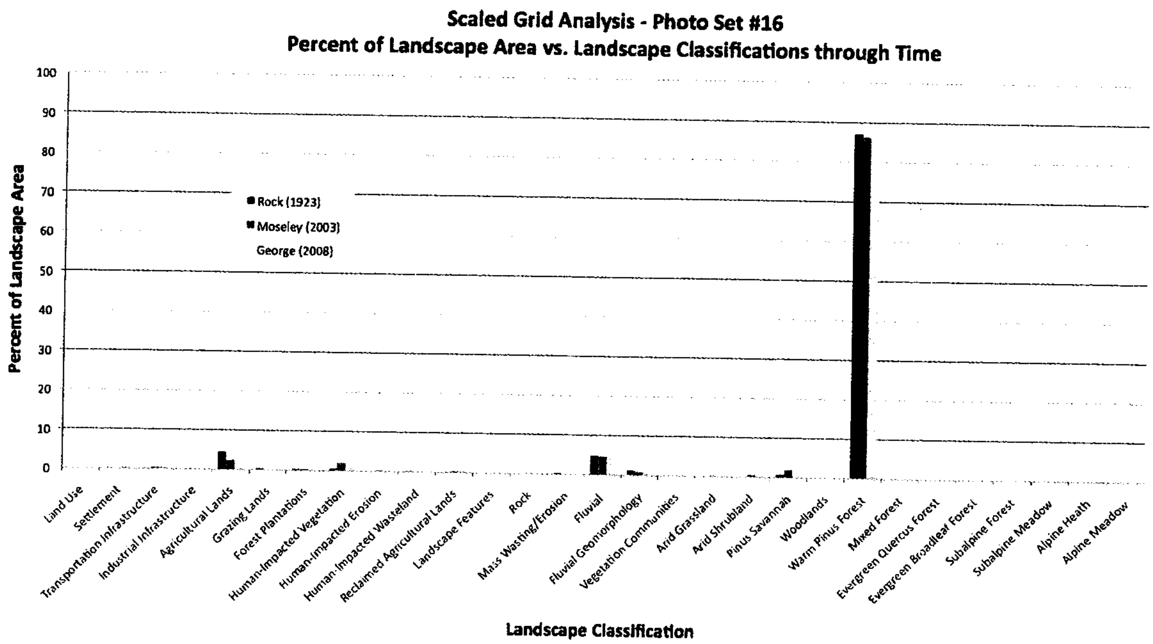


Table F.3 This table shows the empirical results of the scaled grid analysis of Photo Set #16. The first column shows the number of squares occupied by each landscape classification in each photograph (Rock, Moseley, George). The number values are calculated into percentages of the total number of squares in each photograph.

Photo Set # 16- Scaled	Rock (1923)		Moseley (2003)		George (2008)	
	Number	Percent	Number	Percent	Number	Percent
[illegible]	1	0.059	2	0.114	3	0.213
[illegible]	1	0.059	5	0.285	4	0.284
[illegible]	0	0.000	1	0.057	1	0.071
[illegible]	76	4.463	42	2.397	33	2.344
[illegible]	5	0.294	0	0.000	0	0.000
[illegible]	6	0.352	5	0.285	5	0.355
[illegible]	9	0.528	36	2.055	39	2.770
[illegible]	0	0.000	3	0.171	2	0.142
[illegible]	2	0.117	0	0.000	0	0.000
[illegible]	1	0.059	4	0.228	4	0.284
[illegible]	0	0.000	2	0.114	1	0.071
[illegible]	3	0.176	0	0.000	0	0.000
[illegible]	83	4.874	80	4.566	89	6.321
[illegible]	20	1.174	15	0.856	8	0.568
[illegible]	0	0.000	3	0.171	3	0.213
[illegible]	0	0.000	8	0.457	9	0.639
[illegible]	11	0.646	33	1.884	10	0.710
[illegible]	8	0.487	0	0.000	0	0.000
[illegible]	1485	87.199	1513	86.358	1197	85.014
[illegible]	0	0.000	0	0.000	0	0.000
[illegible]	0	0.000	0	0.000	0	0.000
[illegible]	0	0.000	0	0.000	0	0.000
[illegible]	0	0.000	0	0.000	0	0.000
[illegible]	0	0.000	0	0.000	0	0.000
[illegible]	0	0.000	0	0.000	0	0.000
[illegible]	0	0.000	0	0.000	0	0.000