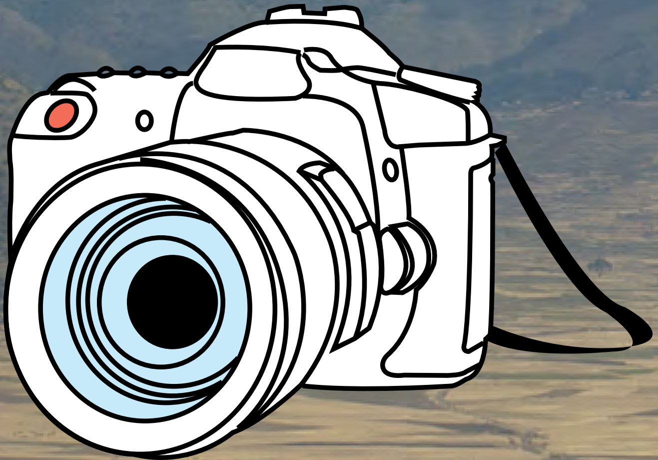
Ground-Based Photo-Monitoring of Landscape Changes Arising from Sustainable Land Management Practices

A Users' Guide



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REGIONAL SUSTAINABLE LAND MANAGEMENT

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Preface

Many contemporary environmental scientists and managers are adopting a refined perspective for addressing complex, interdisciplinary problems. Although a simple notion, the approach first acknowledges that humans are integral parts of the natural world. Accepting this reality leads to a view in which the functioning of human societies and nature are inseparably linked or coupled. This Coupled Human and Natural Systems (CHANS) model links critical resources (e.g., biophysical, socioeconomic, cultural) and social systems (e.g., social institutions, timing cycles, social order) via flows of individuals, energy, nutrients, materials, information, and capital to form a complex, interacting set of organizational, spatial, and temporal couplings (see Figure 1). CHANS thinking comes naturally to applied scientists and practitioners focused on understanding, developing, and promoting sustainable land use practices for the production of food, forage, and fiber.

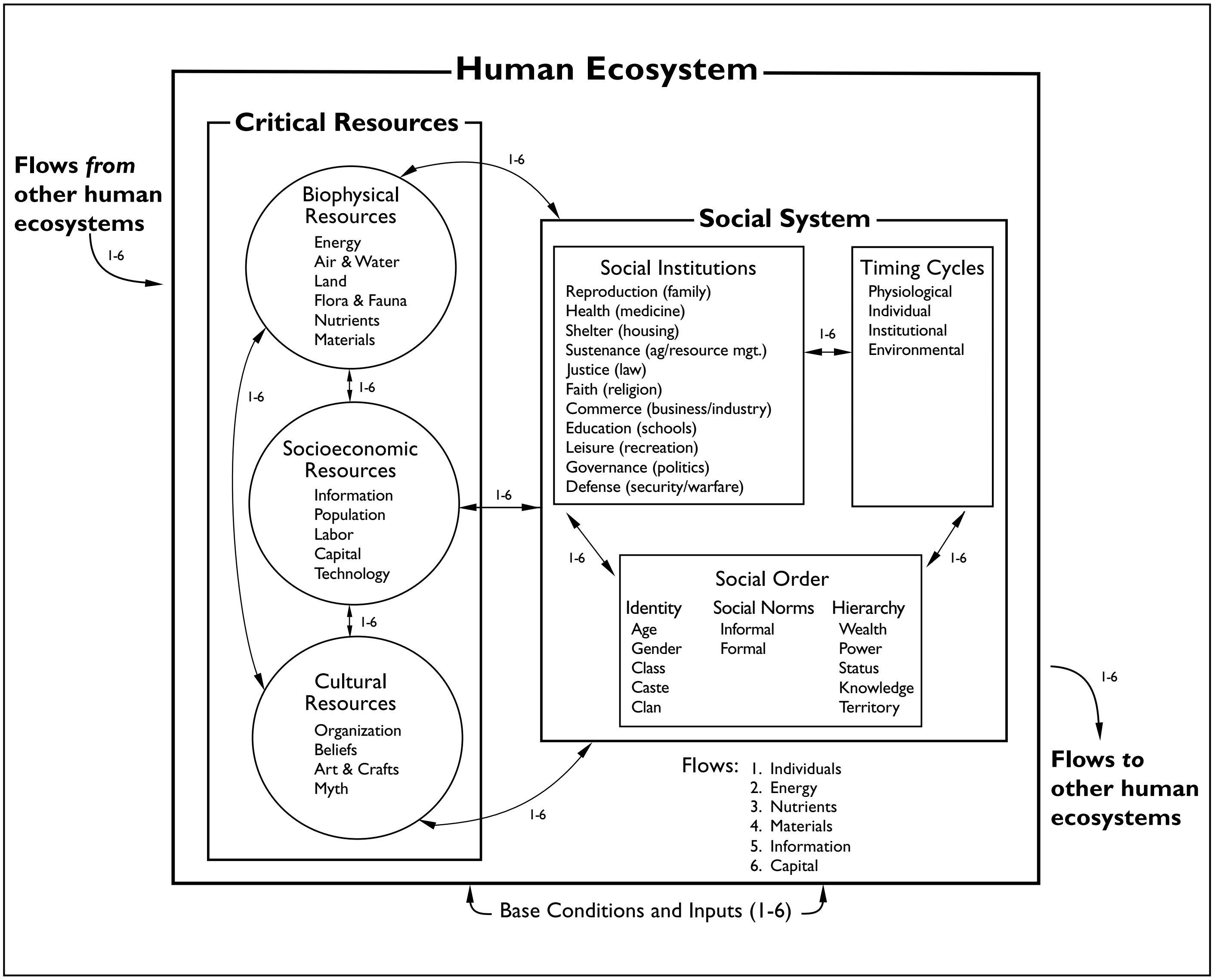
One important benefit of adopting a CHANS approach is that investigators have a wide variety of analytical tools available to them for temporal and spatial analyses, such as systems modeling, analytical chemistry, statistical testing, quantitative and qualitative social surveys, remote sensing, geographic information systems (GIS), etc. These techniques, however, commonly require costly equipment and/or special training. Unfortunately, in the rush to incorporate new analytical tools into projects and programs many older, simpler, and less expensive methodologies are often forgotten or discounted as being "out of date" or "less rigorous."

GIS and remote sensing are powerful tools for land use monitoring and assessment that provide accurate measurements of temporal and spatial variations across landscapes. Therefore, striving to develop the equipment and staff for a GIS facility is a worthwhile goal for land use organizations, such as those developing and implementing conservation, ecoagriculture, or other land management interventions. But, until this becomes a reality or even associated with established GIS capabilities, an often forgotten, simple monitoring tool might be sitting around your project office – a digital camera.

A photographic database of land use changes at ground level will not provide the precision and accuracy of a modern GIS analysis. However, it will provide an inexpensive, easy, and illustrative means for documenting changes over time and communicating complicated ideas to a wide audience. For example, a temporal sequence of GIS maps quantifying hectares of forests cut or crops planted over time would certainly be valuable, but might lack the visual impact afforded by a series of ground-based photographs showing such changes. Consider the value of comparing 'before' and 'after' photographs of a deforested rainforest or a recently established agroforestry system. The optimum, of course, would be to have both.

This users' manual has been specifically designed to encourage and assist land use practitioners in considering the potential benefits of developing a time-series photographic database to support project goals and objectives. Although photography has been around for about 170 years, we will show you new ways to use this old technology. You will see that a properly developed ground-based photo-monitoring survey can provide far more information than merely documenting "before" and "after" situations, thereby greatly supporting project activities, even those where a modern GIS facility is available.

– James Lassoie, Lindsay Myron, and Louise Buck
May 29, 2014



The Structure of Human Ecosystems,V.05.2, Machlis et al (2005)

Figure 1. Human Ecosystem Model for Coupled Systems

Source: www.uiweb.uidaho.edu/hesg/model.html

Acknowledgements

We appreciate the important contributions of many colleagues and associates to the ground-based photo-monitoring methodology that is described in this manual. First, we are grateful to The Nature Conservancy Program in China, and especially Mr. Robert Moseley for providing the inspiration and support for pioneering the development of a GBPM methodology approach to support landscape conservation from which the manual originated. Ms. Kiran Goldman's work in the mountainous regions of Yunnan China to help field test the methodology is also greatly appreciated.

The E.L. Rose Conservancy of Susquehanna County, Pennsylvania was a collegial and generous partner in advancing the GBPM methodology in the context of community conservation management in the northeastern United States. We are grateful to Ms. Jessie Comba who conducted valuable fieldwork in applying GBPM in the subtle terrain of wooded landscape mosaics.

Mr. David Kuria, Director of KENVO, and Dr. Mwangi Guthuru of the Ministry of Higher Education, Science and Technology in Kenya assumed vital roles in developing the case study on GMPM in the Lari Landscape of Kenya. We thank them both, as well as Mr. Jared Crawford of Matthews Safari, and staff members of KENVO who made pilot testing of the methodology in the Kikuyu Forest Escarpment of Kenya feasible and enjoyable.

We are extremely grateful to the national and regional GIZ, MoA, Regional Agriculture and Rural Development Bureau, and Woreda Agriculture offices for their support and participation in the pilot testing of the GBPM approach in the Burqa Abagabir Watershed in Raya Azebo district, Southern Tigray, Ethiopia. The efforts of Mr. Aregawi Gergrekidan, GIZ Deputy Director; Mebrhatom Fekadw, Regional GIZ M&E Advisor; Dr. Helen Laqua, National GIZ M&E Advisor; and Mr. Mulat, Woreda Sustainable Land Management Coordinator were instrumental in preparing the case study. Mr. Ayal Desalegn was our valued partner in conducting the pilot test in Ethiopia without whose guidance and support the preparation of the case study would not have been possible. The support of Raffaela Kozar of EcoAgriculture Partners in liaising with the field team and our hosts in Ethiopia was instrumental to the successful completion of the pilot test and much appreciated as well.

Finally, to our financial supporters, we are grateful to the New Partnership for Africa's Development (NEPAD) and to TerrAfrica, a NEPAD-led partnership present in 24 countries in Africa that supports innovative solutions to sustain landscapes, for their collaboration in producing this guide. And we thank Norad for its generous contribution in bringing the guide to fruition to help strengthen civil society's roles in integrated landscape management.

Contents

Figures

Acronyms

KENVO	Kijabe Environmental Volunteers
GBPM	Ground-based photo-monitoring
GIS	Geographic information system
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Society for International Cooperation)
GPS	Global positioning system
MOA	Ministry of Agriculture
M&E	Monitoring and evaluation
SLM	Sustainable land management
TNC	The Nature Conservancy

Glossary

Aerial Repeat Photography: A method of repeat photography that uses planes, balloons, kites or other airborne vessels from which to take the photographs.

Analytical Framework: A programmatic context for interpreting observable changes in the landscape.

Aperture: A measure of the opening in a lens through which light passes to reach the sensor. Aperture is also called an f-stop.

Datasheets: A data collection template used to collect field information at a photo-point.

Data Logbook: A notebook used to collect field information at a photo-point.

Database Management Representative: An individual or group of individuals in a GBPM team that is capable of processing and managing large amounts of data in selected software (e.g. GIS, Excel).

Depth of Field (DOF): The distance between the nearest and farthest objects that are in sharp focus in an photograph. DOF increases as the aperture decreases.

Digital Single-Lens Reflex (DSLR): A type of digital camera which passes light through an optical lens to a mirror, which either reflects the light up to the viewfinder or to a digital image sensor.

Focal Length: The distance between a center of a camera's lens or curved mirror and its focus.

Forward-Sampling: A method of sampling in which a baseline is established in the present and repeats are sampled in the future (as opposed to the method employed in historical repeat photography).

Frame: The rectangular area in which an image is composed in a camera.

GPS Receiver (or GPS Navigation Device): A receiver that determines its position (latitude and longitude) by analyzing the satellite signals it receives through the US-based Global Positioning System (GPS), thereby allowing the user to determine and record his or her precise location.

Ground-Based Repeat Photography: Synonymous with ground-based photo-monitoring. A method of repeat photography in which photographs of the landscape are taken at ground level (as opposed to aerial repeat photography).

Ground-Based Photo-Monitoring (GBPM): A method of documenting and assessing visual changes in a landscape over time by repeatedly taking photographs from the same location at ground level.

Historical Repeat Photography: A method of finding old photographs (generally 25 years old or older) that are then juxtaposed with present-day repeat photographs from the same location.

Images: Pictures or photographs taken with purpose to record and store important, useful visual data.

Image Database: An organized system or library of GBPM images and data.

ISO: A measure of a camera's image sensor sensitivity to light. A high ISO number indicates a very sensitive sensor, v.v.

JPEG: A type of digital image format that compresses the raw data into a smaller, more manageable size, which consequently reduces the image quality.

Keywords: Words that describe visual indicators of change and correspond with the analytic framework used to decide what natural resource characteristics and/or human activities to monitor using the GBPM method.

Memory Card: A small, flat flash drive used to save image files on a camera.

Opportunistic Sampling: A sampling technique in which photo-points to be sampled are selected based on their ease of accessibility within the landscape.

Overlap: A technique used for capturing panoramas in which one fifth of the first frame is realigned to fit in the opposite fifth of the next frame.

Panorama: A series of photographs that, when strung together, depict an unbroken view of a wide area.

Photography Representative: An individual or group of individuals on a GBPM team that is comfortable working with cameras and related equipment.

Photo-Monitoring: A method of documenting and assessing visual changes in landscapes over time by repeatedly taking photographs from the same location.

Photo-Point: A geographic location from which photos are taken in a GBPM survey.

Point & Shoot: A type of digital camera that is lightweight, compact, and uses autofocus among other automatic settings.

Quota Sampling: A sampling technique in which photo-points are selected from an assortment of mutually exclusive sub-groups at a certain proportion (e.g. 10 wetlands, 10 rivers).

Random Sampling: A sampling technique in which photo-points to be sampled are selected at random prior to visiting the field and are precisely located in the landscape.

Repeat photography: (see photo-monitoring).

Representatives: A specific role within a GBPM team that possesses the necessary characteristics, skill sets, and traits.

SD Card: A style of memory card used in many digital cameras, especially point & shoot.

Shutter Speed: A measure of how fast a camera's shutter opens and closes to allow light to pass through and reach the image sensor.

SLM Projects Representative: An individual or group of individuals on a GBPM team that is knowledgeable of area land degradation, sustainable land management projects or initiatives to address those threats, and the anticipated or potential outcomes.

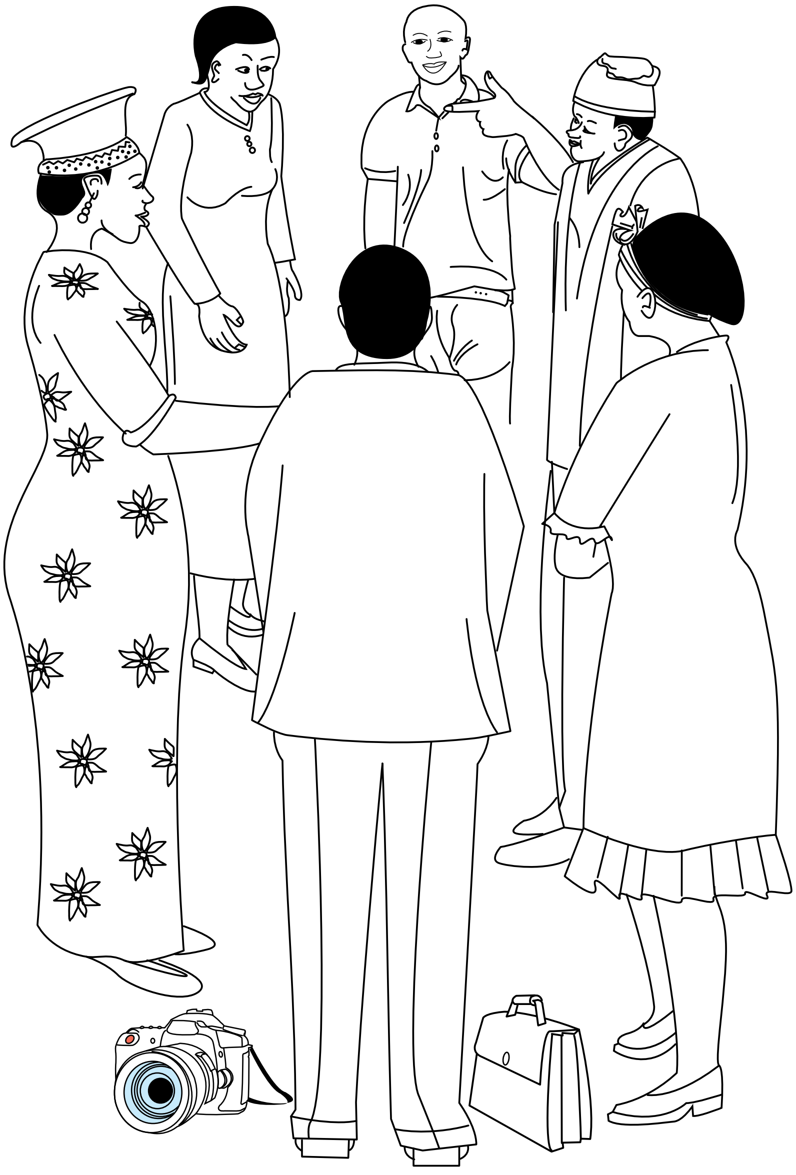
Spatial Representative: An individual or group of individuals on a GBPM team that is knowledgeable of the landscape, including its daily and seasonal weather patterns, accessibility routes, and biophysical and ecological characteristics.

Strategic Sampling: A sampling technique in which photo-points are selected based on their likelihood of potential change or the presence of a specific feature, as outlined in the analytical framework. Photo-points can also be selected while in the field, wherever an opportunity arises.

Tagging: A method of cataloging images, in which keywords are linked to photos in an image database.

Waypoint: A location of interest, or a reference point on a route, stored as latitude-longitude coordinates and often captured by a GPS receiver.

White Balance: A setting on a camera to adjust the color balance of light depicted in the resulting images.



Part 1

Introduction

What is Photo-Monitoring?

Photo-monitoring is a method of documenting and assessing visual changes in landscapes over time by repeatedly taking photographs from the same location. Another term frequently used to describe photo-monitoring is repeat photography, which includes such methods as historical repeat photography, aerial repeat photography, and ground-based repeat photography.

Historical repeat photography is a method that first locates old photographs (generally 25 years old or older) that are then juxtaposed with present-day photographs taken at the same location to document ecological, cultural, and/or socioeconomic changes that occurred since the original images were taken. The practice entails finding the original site of a historical photograph, placing the camera in the same position, and re-photographing the scene. This method is generally exploratory; illustrating what has happened in the time elapsed without necessarily having expectations of change (USFS 1994). Although this method should not be excluded from photo-monitoring efforts aimed at assessing changes from sustainable land management (SLM) initiatives, one must be aware of its immediate limitations. For example, the lack of historical images or their poor quality, the potential for bias from the original photographer, his/her manipulation of the environment prior to taking the photograph, and the sheer difficulty in identifying and replicating an image in its spatial and temporal context are all probable pitfalls of this particular method. Still, when old photographs are available, this method can yield some interesting and sometimes startling insights into changing landscapes (e.g., see: www.nrmsc.usgs.gov/repeatphoto/overview.htm and Moseley 2006).

Aerial and ground-based repeat photography establish a forward-looking system whereby photographs taken at a sample of locations in a landscape and are then retaken over time to document future ecological, cultural, and/or socioeconomic changes. Both methods may also include historical photographs. Aerial repeat photography refers to the use of airplanes, balloons, kites, or more recently drones from which images are taken (Marzolff et al. 2011), whereas ground-based repeat photography refers to photographs taken in the field at ground level.

All three of these methods can be valuable tools for documenting ecological and land use changes, and when tied to an analytical framework for assessing visual changes over time, they become useful monitoring tools. While repeat photography and photo-monitoring are sometimes used interchangeably, we will refer to the methodology presented in this manual as ground-based photo-monitoring.

The Basics of Ground-Based Photo-Monitoring (GBPM)

Although photography was developed and made known to the public in the 1830s, it was not until the 1960s that ground-based photography was used in a systematic way to monitor changes in vegetation and land-use over time. In 1965, J. R. Hastings and R. Turner's The Changing Mile defined repeat photography and showed how it could be used to examine human and climate impacts on vegetation change in the Southwest United States and Northwest Mexico. In the near 50 years since, GBPM has become a commonly used tool worldwide to help monitor and assess vegetation and ecological change (see Appendix A: Annotated Bibliography). Comprehensive coverage of this methodology is available free-of-charge online (Hall 2001; 2002) or in a more recent handbook by Webb et al. (2010), which also offers an excellent historical review of repeat photography. Adapted from this earlier work, the methodology presented in this manual is based on past work in the mountainous regions of Northwest Yunnan, China by Lassoie et al. (2006).

Photographing a landscape or a SLM project is commonplace and becoming a practice frequently used by practitioners, researchers, and monitoring and evaluation (M&E) specialists. However, the power of those photographs in tracking ecological and land use change is often forgotten or lost either in the depths of one's photo files and to other monitoring tasks that take precedence. Given the availability of detailed spatial information from geographic (GIS) and remote sensing systems and their useful application to monitoring land-use changes, one might see GBPM as a technological step backwards. Without question, the quantification of large-scale changes resulting from SLM initiatives can best be measured using sophisticated approaches and rigorous scientific studies, and they will not be replaced in-kind with GBPM. Moreover, certain funding sources or managing organizations and institutions require specific or standardized M&E methods, which cannot be avoided or replaced. However, the qualitative assessments arising from GBPM can provide unique, useful insights to supplement GIS data and strengthen existing M&E methods. Additionally, in cases where remote sensing techniques are prohibited (e.g., Lassoie, et al. 2006), unavailable, or too costly, GBPM might provide a relatively easy, cost-effective approach to M&E.

In any situation, GBPM offers distinct advantages for assisting SLM initiatives in that:

1. it uses readily available equipment and is relatively inexpensive, technically simple, and easily accessible by a wide variety of individuals;
2. photographs are easily understood and provide opportunities for interpretation by scientists, practitioners, and local community members of any education level;
3. when used with an appropriate analytical framework, changes in visual indicators can be linked to management goals and outcomes;
4. photographs offer a visual base for group discussions of management plans and outcomes;
5. photographs and their interpretations are easily communicated in public meetings, professional workshops and conferences, scientific publications, project reports, and outreach bulletins; and
6. photographs can be integrated easily into existing or future GISs, such as Google Earth or ArcGIS (www.youtube.com/watch?v=TeGFd7d80EM).

The methodology is not without its limitations, however. Aside from the precision constraints presented by different technologies and equipment, GBPM and its resulting assessments may be limited in that:

1. only changes that are visible and large enough to be recorded by a camera can be detected;
2. changes in operators and equipment may affect results;
3. representation of objects may be biased by the photographer or restricted by the image's frame size or the number of images taken;
4. while photographs can measure qualitative changes in an object's number or size within the frame, they have limited accuracy for quantifying inventories within a landscape;
5. external effects, such as season, time of day, and weather may cause photographs to suggest greater changes than have actually occurred; and
6. photographs may not provide sufficient evidence of causal relationships in the object or variable of interest.

Objectives and Structure of This Manual

This manual has been developed specifically for SLM researchers and practitioners working in Sub-Saharan Africa to aid in the development a GBPM program for tracking land use and land cover changes following project implementation. Following this introduction (Part 1), the manual is divided into the following sections.

Part 2 will help researchers and practitioners understand the capabilities and limitations of the GBPM methodology, thereby helping them decide whether this approach is appropriate for the monitoring and evaluation of their specific projects.

Part 3 is designed for those interested in adopting this methodology. It offers a step-by-step guide on how to develop and implement a GBPM survey. Six steps are discussed:

1. assembling a GBPM team;
2. developing a visually descriptive analytical framework based on project objectives;
3. selecting representative landscapes and devising an appropriate sampling scheme;
4. photographing the landscapes and collecting data;
5. organizing, analyzing, and storing the photographs; and
6. comparing images over time.

Part 4 provides two examples of GBPM in practice in Sub-Saharan Africa. These case studies include GBPM surveys in Kenya and Ethiopia to demonstrate the use of the GBPM methodology in different applications and regions. References comprise Part 5 of the manual.

Lastly, two appendices offer supplemental information and resources that are referenced in the manual, including an annotated bibliography, and a basic orientation to GBPM equipment.

If GBPM is a method you are possibly interested in applying, we recommend that you first review this entire manual, paying particular attention to Part 2. Then, carefully work through the steps presented in Part 3 using the case studies in Part 4 for illustration and clarification. Refer to the Annotated Bibliography if you seek information that is not presented in the manual or if our discussion does not fully meet your specific needs. Note that the Annotated Bibliography includes some references not cited in the manual.

Part 2

Deciding to Use GBPM

In this section you will:

Learn about the potential benefits arising from adopting the GBPM method.

Gain a basic understanding of where GBPM is applicable and the work it entails to implement.

Determine whether GBPM is an appropriate monitoring method for your specific SLM project.

Historical GBPM in Action

The potential benefits arising from GBPM can be quickly illustrated by examining different landscapes where historical photographs are compared with current-day photographs within a GBPM system. Three examples are presented below that represent very different landscapes and geopolitical settings: Northwest Yunnan, China; Pennsylvania, USA; and Northern Ethiopia. These examples demonstrate the types of benefits you might derive from a forward-looking GBPM survey.

Northwest Yunnan, China

This GBPM methodology was originally developed to monitor conservation programs by The Nature Conservancy in mountainous landscapes of Northwest Yunnan (Lassoie et al. 2006). It expanded on the historical repeat photography work of Robert K. Moseley (Moseley, 2006; Moseley and Tang, 2006; Baker and Moseley, 2007, Moseley, 2011) in the same region[1] by developing a photographic baseline for monitoring future change and framework for analysis of repeat photographs (discussed later in this manual).

At its simplest analysis, Moseley's GBPM survey from Yunnan provided a qualitative assessment of changes in land cover, land use, and vegetation over about a 90-year period. In his study, historical and current images were described according to different land use categories (see Table 1); most images contained more than one category. Comparisons between historical and current images were made for each pair and the change in each land use category was determined. The percentages of image pairs that showed an increase, decrease, or no change in each land use category are shown in Table 1. Qualitative assessments of ecological and land use changes were then possible (e.g., extent of municipalities increased while crop fields

Land Use Category	*# of Comparisons*	*No Change (%)*	*Increase (%)*	*Decrease (%)*
Municipal	40	30	65	5
Crop Fields	52	22	38	40
Arid Shrub	32	44	16	40
Woodland	20	35	65	0
Subalpine Forest	26	54	27	19
Alpine Meadow	25	52	16	32
Glacier	17	0	0	100
Woodland	20	35	65	0
Subalpine Forest	26	54	27	19
Alpine Meadow	25	52	16	32
Glacier	17	0	0	100

Table 1. Summary of changes in area or density of land cover, land use, and vegetation shown for 115 photo comparisons from Northwest Yunnan, China.

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[1] Moseley's study was possible because of the exploits of early plant-hunters and explorers who photographed their travels through the region for later sale to magazines such as the National Geographic (e.g., Joseph Rock; see www.josephrock.net and www.pratyeka.org/rock/).

remained relatively constant), but did not allow cause and effect interpretations (e.g., increasing populations did not need more crop land because of agricultural intensification). Such qualitative assessments, however, can form the basis for further study; for example, the uniform decrease in the extent of glaciers (Baker and Moseley, 2007). Those interested a more complete ecological interpretation of image pairs from Northwest Yunnan should see the book by Moseley (2011).

Pennsylvania, USA

The E.L. Rose Conservancy of Susquehanna County in Pennsylvania, USA employed a GBPM survey between 2004 and 2008 to track changes in the county's land use over the past century and to establish a baseline to monitor future changes (J. Lassoie, L. Myron, and J. Comba, unpubl.). The rich historical photograph archive maintained by the Susquehanna County Historical Society in Montrose, Pennsylvania made the study possible. Historical photos

Figure 2. Repeat images of the Snake Creek Valley, Pennsylvania taken in 1920 (left) and 2008 (right).

Figure 3. Repeat Images of the Lackawanna Trail, Pennsylvania taken circa 1900 (left) and 2008 (right).

Figure 4. Repeat images of Lord's Pond, Pennsylvania taken in 1912 (left) and 2008 (right).

were collected and staff at the society helped identify their original locations and visible landmarks. Many of the historical images depicted this rural county's lakes and rivers; agricultural landscapes; and other developments of the time such as churches, schools, and mills. Repeat photographs were taken throughout the project's duration (see Figures 2-4).

Image comparisons showed many changes to the vegetation cover of hillsides and waterways (e.g., increased deciduous forest and riparian growth), developments in county infrastructure (e.g., roads and electric power lines), and other land use changes associated with economic development (e.g., natural gas drilling and mining). By contrast, some image pairs showed that other aspects of the county remained unchanged, such as dairy farms and agricultural fields, lakeside residential and community settlements, and the historical stonewalls and buildings. In addition to the historical repeat photographs taken, photo-points were established along road transects throughout the entire county and over 800 images were taken for future image comparisons.

Northern Ethiopia

The value of finding and using such historical photographs was also recently illustrated in an examination of desertification in Northern Ethiopia (from Nyssen, et al. 2009; Abstract, pg. 2749):

> A collection of sepia photographs, taken during Great Britain's military expedition to Abyssinia in 1868, are the oldest landscape photographs from northern Ethiopia, and have been used to compare the status of vegetation and land management 140 years ago with that of contemporary times. Thirteen repeat landscape photographs, taken during the dry seasons of 1868 and 2008, were analyzed for various environmental indicators and show a significant improvement of vegetation cover. New eucalypt woodlands, introduced since the 1950s are visible and have provided a valuable alternative for house construction and fuel-wood, but more importantly there has also been locally important natural regeneration of indigenous trees and shrubs. The situation in respect to soil and water conservation measures in farmlands has also improved. According to both historical information and measured climatic data, rainfall conditions around 1868 and in the late 19th century were similar to those of the late 20th/early 21st century. Furthermore, despite a ten-fold increase in population density, land rehabilitation has been accomplished over extensive areas by large-scale implementation of reforestation and terracing activities, especially in the last two decades. In some cases repeat photography shows however that riparian vegetation has been washed away. This is related to river widening in recent degradation periods, particularly in the 1970s–1980s. More recently, riverbeds have become stabilized, and indicate a decreased runoff response. Environmental recovery programmes could not heal all scars, but this study shows that overall there has been a remarkable recovery of vegetation and also improved soil protection over the last 140 years, thereby invalidating hypotheses of the irreversibility of land degradation in semi-arid areas. In a highly degraded environment with high pressure on the land, rural communities were left with no alternative but to improve land husbandry: in northern Ethiopia such interventions have been demonstrably successful.

The potential benefits one can derive from a GBPM analysis are evident, whether one begins with historical photographs or starts anew. Certainly, adding old photographs to a GBPM system can provide a valuable, and often surprising, historical perspective on baseline trends as a context for current SLM activities and future changes. However, as mentioned earlier, historical repeat photography is opportunistic in that it must rely on finding old photographs and being able to locate the original camera location. Furthermore, its ecological and land use interpretative power is compromised by the intention of the original photographer, the quality of the original photographs, an incomplete and potentially misrepresentative sampling design, and a limited analytical framework for interpreting ecological changes (Lassoie, et al., 2006). Therefore, this method should be used as an analytical M&E tool with some caution. A properly designed forward-sampling GBPM system can overcome most of these limitations.

Why Use GBPM?

Maintaining photographic records is helpful to the researchers, managers, extension agents, and farmer practitioners involved in sustainable land management (SLM) practices. The human memory is ephemeral and barring abrupt, large-scale natural disasters or land use modifications, vegetative and related ecological changes in terrestrial landscapes normally proceed at paces not easily detected by humans. While efforts to map land degradation are advancing, efforts to monitor the effects of SLM have been neglected (Liniger et al. 2011). Turning attention to these efforts is significant, as effective monitoring and evaluation of SLM practices has the potential to both communicate results to local communities and managing institutions as well as guide decision-making and warrant further investment in SLM best practices.

Photographs provide indisputable visual records and important mental cues of the long-term and far-reaching changes in landscapes. In addition, photographs can serve as an effective tool for communication, especially across barriers of language, literacy, knowledge, and experience. Without accompanying documentation, however, a photograph can quickly become a nondescript 'snapshot' once separated from the photographer (see Figure 5).

Figure 5. Without supporting documentation (e.g., where, why, or who) the significance of the beehives in this image is lost.

Moreover, without an organized system of storage, digital photographs are easily 'misplaced' or lost within the many files of one's computer. By developing a systematic approach to taking and storing pictures (i.e., GBPM) this pitfall can be easily avoided and the resulting images will provide useful information now, and into the future.

The first step is to accept the importance of having a photographic record of your SLM practices. In today's world, digital cameras, even in cell phones, are ubiquitous and billions of digital photos (mostly 'snapshots') are generated annually. Hence, we expect that very few SLM professionals and practitioners would totally dismiss the roles that photographs can play in their work. But, a critical transition comes from recognizing photographs as information themselves – visual data that can be as important as any other data collected before, during, and after a project. In order to emphasize this distinguishing characteristic, we will refer to these photographs as **images** – pictures taken with purpose to record and store important and useful visual data.

Of course, there are many kinds of image records, from the simple to the complex. Specifically, GBPM implies assessing changes over time (i.e., T0, T1, T2. etc.), and having a standardized means for interpreting those changes relative to project objectives. However, the importance of documenting all images that illustrate significant management activities, even those that are static, should not be minimized. Recall the example from Susquehanna County, Pennsylvania; although the technique can be targeted to document anticipated changes in the landscape, results that illustrate any change, even no change, are valuable.

A Key Distinction: The Analytical Framework

A photo-monitoring system is much more than just images taken during the workday or while on a fieldtrip. As just mentioned, accompanying documentation is a critical part of what separates a GBPM survey from taking everyday snapshots, regardless of how interesting they might be at the time. This documentation can be understood by answering the most basic questions (i.e., who, what, where,

Target	*Threat*	*Target Health Category*	*Visual Indicators*
Evergreen Oak Forest	Fuelwood	Size	Clearing
		Condition	Structural changes Extraction methods
	Livestock bedding	Condition	Structural changes
	Tourism and infrastructure	Size (loss of native habitat) Condition (erosion, pollution) Landscape context (fragmentation)	Roads, buildings and structures for tourism, Trails, cableways and billboards
	Mining	Size (loss of native habitat) Condition (erosion, pollution) Landscape context (fragmentation)	Mines, roads, waste material, buildings, impacts to hydrology, evidence of soil

Table 2. Example of keyword indicators for different threats to the evergreen oak forest target in the Hengduan Mountains Ecoregion, Northwest Yunnan, China (from Lassoie et al. 2006).

when, why, and how) about your landscape, your SLM initiative and, eventually, your GBPM survey.

First, GBPM images must be rooted within an **analytical framework**, a set of visual indicators, or **keywords** (i.e., the what and why) that are based on the landscape and the objectives of the SLM project being implemented. Developing the what and why of an analytical framework may prove difficult and time consuming depending on the depth of analysis desired, but this step is critical. The process of developing the analytical framework will require both input from project managers, M&E specialists, and local community members as well as research into project planning documents, M&E or progress reports, and other relevant materials. With focused discussion and collaboration, your analytical framework and resulting list of keywords will be unique to your project and region, thereby enabling a targeted and effective qualitative assessment of landscape change.

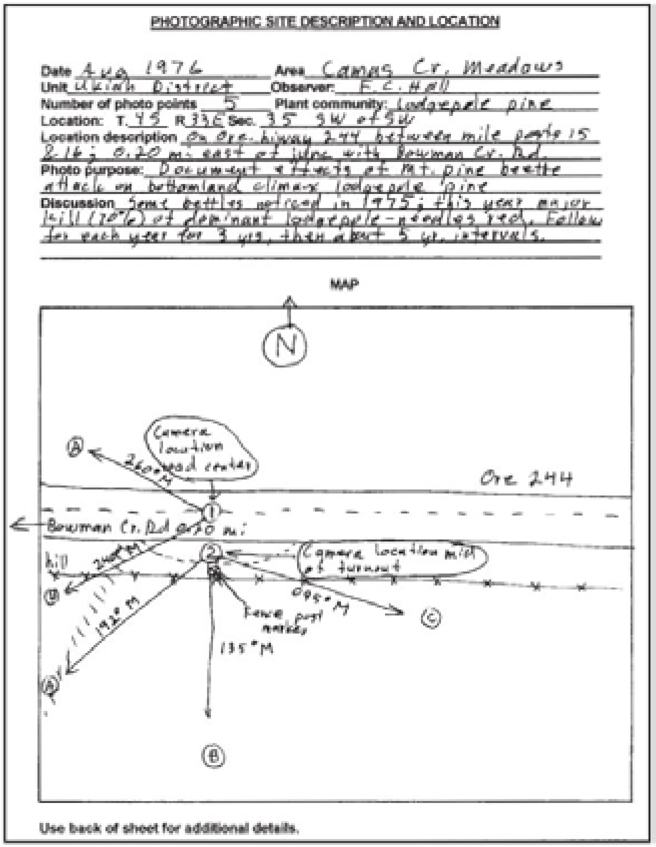
For example, developmental work in China with The Nature Conservancy (TNC) (Lassoie et al. 2006) had the benefit of building a GBPM system that was supported by a detailed conservation framework called Conservation by Design (TNC, 2001). It uses an adaptive process to identify conservation targets, threats to these targets, and target health categories in order to focus conservation initiatives. In designing the GBPM analytical framework, visual indicators were identified for each Target-Threat-Health combination and used as keywords (see Table 2). These keywords were then used to describe individual images in a searchable database. Employing this system over time provides a means for assessing changes by examining a series of repeat photographs.

Second, GBPM images must be precisely located (i.e., where) and the time and date (i.e., when) need to be documented so that repeat images can be taken over time from the same position under comparable daylight and seasonal conditions. Additional information, such as how (i.e., camera type, image resolution, and exposure settings) and who (i.e., photographer, knowledge, experience) is also important, but secondary.

The when, where, who, and how aspects of a GBPM image can be easily recorded with some minimal planning and forethought. Drafting a simple field datasheet or using a data logbook while in the field will help you record and keep organized all of this important information. For example, Hall (2001; 2002) created an in-field worksheet (see Figure 6a and b) to complete at each photo-point and used an organized filing system to catalogue these data for future use. Hall's work used film cameras, which required more precautionary attention to keeping these data organized while in the field. Digital photography has an advantage in this regard and various technologies exist to simplify this process. For instance, provided that the internal clock is accurately set, digital cameras will automatically record the time and date in the image's metadata, which can be accessed on a computer at any time. Additionally, certain cameras and adapters make it possible to record GPS and other information within the metadata as well, even keywords or field notes (See Appendix B: GBPM Equipment). The case studies in Kenya and Ethiopia, found in Part 4 of this manual offer examples of data logbooks.

What Kind of Work Does GBPM Entail?

As with any new project or M&E endeavor, you will be introducing new tasks and responsibilities into your organization's and employees' workflows. First, GBPM will require some planning and strategizing, which must be completed at the forefront of the project by a team of

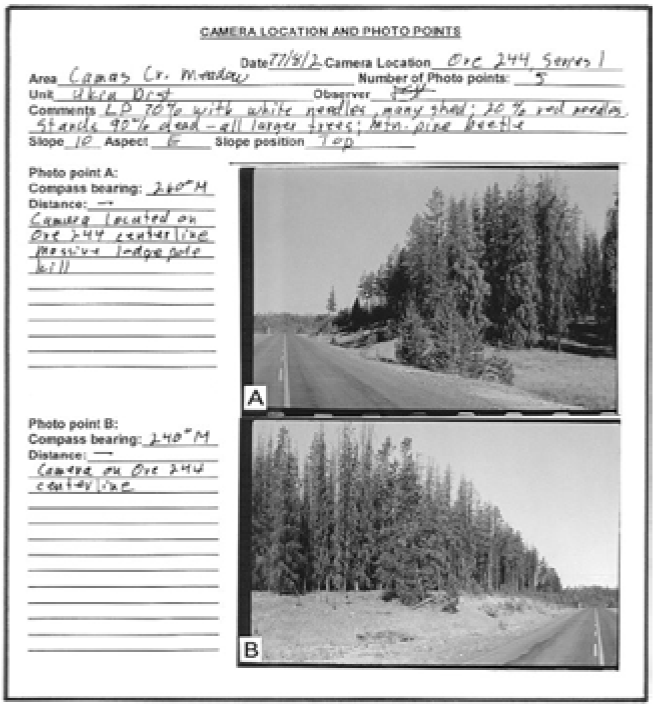


PHOTOGRAPHIC SITE DESCRIPTION AND LOCATION

Date Aug 1976 Area Camas Cr. Meadows
Unit Ukiah District Observer: F. C. Hall
Number of photo points 5 Plant community: lodgepole pine
Location: T. 4S R 33E Sec. 35 SW of SW
Location description On Ore. hiway 244 between mile posts 15 & 16; 0.20 mi. east of junc with Bowman Cr. Rd.
Photo purpose: Document effects of Mt. pine beetle attack on bottomland climax lodgepole pine
Discussion Some beetles noticed in 1975; this year major kill (70%) of dominant lodgepole - needles red. Follow for each year for 3 yrs, then about 5 yr. intervals.

MAP

Use back of sheet for additional details.



CAMERA LOCATION AND PHOTO POINTS

Date 77/8/2 Camera Location Ore 244, Series 1
Area Camas Cr. Meadow Number of Photo points: 5
Unit Ukia Dist Observer
Comments LP 70% with white needles, many shed; 30% red needles. Stands 90% dead - all larger trees; Mtn. pine beetle
Slope 10 Aspect E Slope position Top

Photo point A:
Compass bearing: 260° M
Distance: —
Camera located on Ore 244 centerline massive lodgepole kill

Photo point B:
Compass bearing: 240° M
Distance: —
Camera on Ore 244 centerline

Figure 6. Left: photographic site description and location form used by frederick hall. Right: camera location and photo points form used by frederick hall. (Hall 2002)

individuals. Designing the analytical framework may be time-intensive depending on the depth of analysis desired. If you gather input from a few knowledgeable people or groups and reference some key reports and documents, however, you will find that this step is simply a compilation of existing information and quite complementary to current work.

The integration of historical photographs into a GBPM survey, if you so choose, will certainly add to your workload. Finding historical photographs, relocating, and re-photographing the scenes may prove to be a very time-consuming process, but as mentioned earlier, the benefits derived can be invaluable to your project.

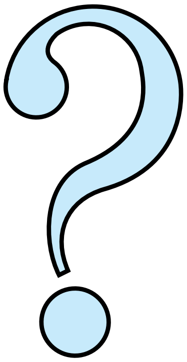
Designing a sampling scheme for your GBPM survey will depend upon which features or drivers of change you are seeking to monitor. You may already be well aware of where you would like to survey, in which case, this step will consume little of your time. If not, some input from M&E and SLM specialists and perhaps from affected groups (e.g., farmers, community members) can quickly identify where and how you will want to sample.

The data collection (i.e., taking pictures) can be integrated into other field trips to the areas you will be monitoring or it can become a trip in itself. Depending on the frequency at which you want to repeat your data collection and the time and personnel you have available, this can occur once a month, once a year, or even once every decade depending on the frequency of landscape changes you anticipate.

The data analysis and storage will likely be the most time consuming aspect of a GBPM survey and will require some equipment, dedication, and organization. Transcribing field data and tagging images can be a shared task or the responsibility of one individual. While it may seem tedious in the moment, it will prove beneficial in the future and should not be undervalued. Organizing an image database can be facilitated by various types of computer software, but simple Excel spreadsheets and well-organized image files are often sufficient. Lastly, maintaining a GBPM database will require periodic updates of software and backing up images and their descriptive information.

As mentioned earlier, the work associated with a GBPM survey can be shared among a team of individuals or become the responsibility of one individual depending on the resources and personnel you have available. Moreover, community participation can be integrated at various stages of the project, regardless of experience or education. Community involvement has the potential to both lessen your staff's workload and also facilitate communication and stimulate discussion of SLM impacts to those who are most affected.

A detailed description of the work that goes into a GBPM survey is provided in Part 3. For now, the following focus questions will help you decide whether establishing a GBPM system would be applicable, possible, and beneficial for your project. Before making your decision, you may want to continue reading Parts 3 and 4 to gain insight into the applicability and potential of GBPM.



Focus Questions

Do historical photographs exist for your region and if so, would you be able to gain access to them?

Would comparative photographs (i.e., GBPM) strengthen your communication efforts with community members, your organization, participating institutions, and/or your benefactors?

Would GBPM be complementary to your current M&E efforts? Do you already take photographs of your SLM projects?

What kinds of systems or resources do you have in place for documenting and storing reports or other records of your SLM projects (e.g., GIS, online database, office computers, hard-copy files)?

Are you seeking to monitor large-scale or small-scale features or drivers of change within your landscape?

Who would be willing, able, and/or interested in participating in a GBPM survey? What knowledge or skill sets do you have available (e.g., community members familiar with the landscape and its history or GIS, SLM, and M&E advisors)?

Part 3

Building a GBPM System for a Sustainable Land Management Project

This part of the manual provides a detailed guide for those interested in developing a comprehensive GBPM system to support a monitoring and evaluation (M&E) program for sustainable land management initiatives in Africa. The critical steps in this workflow include: (1) developing your GBPM team; (2) defining the objectives of the GBPM system (i.e., analytical framework); (3) identifying representative landscapes within your project area, selecting representative plots within those landscapes, and establishing appropriately located GBPM photo-points (i.e., sampling design); (4) photographing the landscapes/plots (i.e., data collection); and (5) organizing, analyzing, and storing the images (see Figure 7).

Each step is described below and a series of focus questions is listed at the end of some sections for discussion among your GBPM team. We recommend that you read Part 3 in its entirety as well as the case studies presented in Part 4 before beginning.

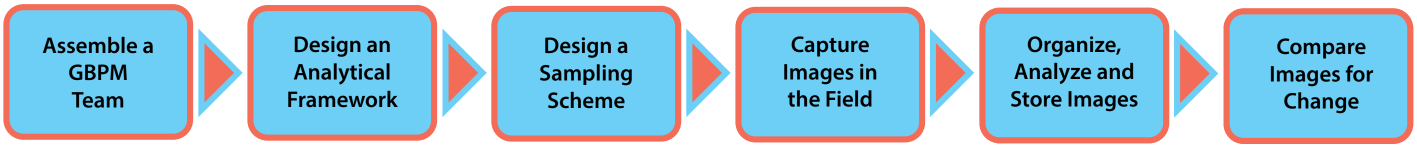


Figure 7. A basic diagram of the suggested workflow for Ground-Based Photo-Monitoring.

Step 1 • Assembling Your GBPM Team

In this section you will:

Learn the knowledge base and skills that you will need to develop a GBPM system.

Learn how to assemble a team of individuals for planning and implementing a GBPM system.

GBPM is a simple methodology involving relatively inexpensive equipment, especially as compared with other approaches to spatially monitoring landscape changes. However, as with any research and M&E methodology it requires skills, care, and commitment if useful visual data (i.e., images) are to result. A land management project team must integrate GBPM into their work plan, which requires committing time, personnel, and some financial resources to developing, conducting, and using the GBPM methodology. While it is possible for a single individual to execute a GBPM survey from start to finish, assembling a GBPM team will generate more clarity and significance as well as lighten the workload for those involved. Hence, assembling a team of dedicated individuals to carry out the various aspects of a GBPM system is the first step in the GBPM workflow.

Several roles are important for organizing and executing a GBPM survey. While we suggest that one individual fill each role, the roles are flexible and can be mixed, matched, or

Role	*Background & skill-sets*	*Primary responsibilities*
Spatial Representative	Familiar with the landscape, including topography, accessibility, weather patterns, species diversity, and history. Also has access to area maps.	Advises the development of the analytical framework and sampling scheme
Land Management Project Representative	Knows the landscape's problems and baseline status, knows the SLM projects and technologies being applied in the landscape, and knows what success / failure might look like.	Advises the development of the analytical framework, sampling scheme, and some database management.
Photography Representative	Knows how to operate and care for camera(s) and equipment, understands basics of digital photography and the limits of the visual data, capable of collecting field data, and able to facilitate community participant photographers in data collection.	Advises the development of the analytical framework, sampling scheme, and database management as well as conducts and/or advises the field implementation.
Database Management Representative	Knows how to organize and store large amounts of data, comfortable working with computers and relevant software (e.g. GIS, Excel, Adobe Lightroom), capable of managing and backing-up database, capable of tagging images to create a searchable database	Advises the development of the analytical framework, facilitates data collection from Photography Representative and/ or community members, and conducts the database management (i.e. organization, analysis, storage).

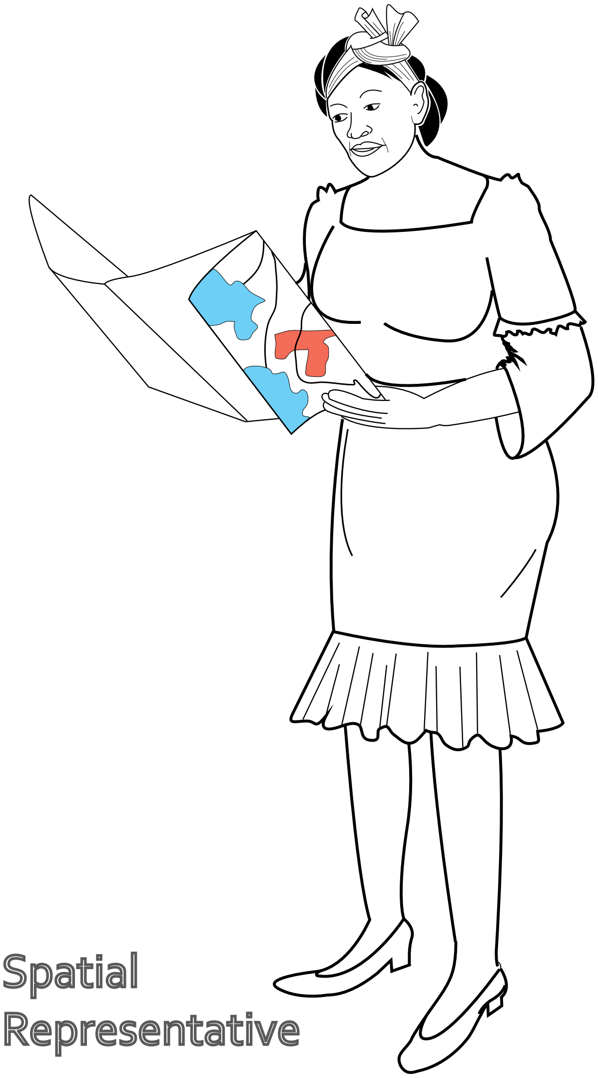
Table 3. A summary of the primary roles needed to establish and execute a GBPM survey.

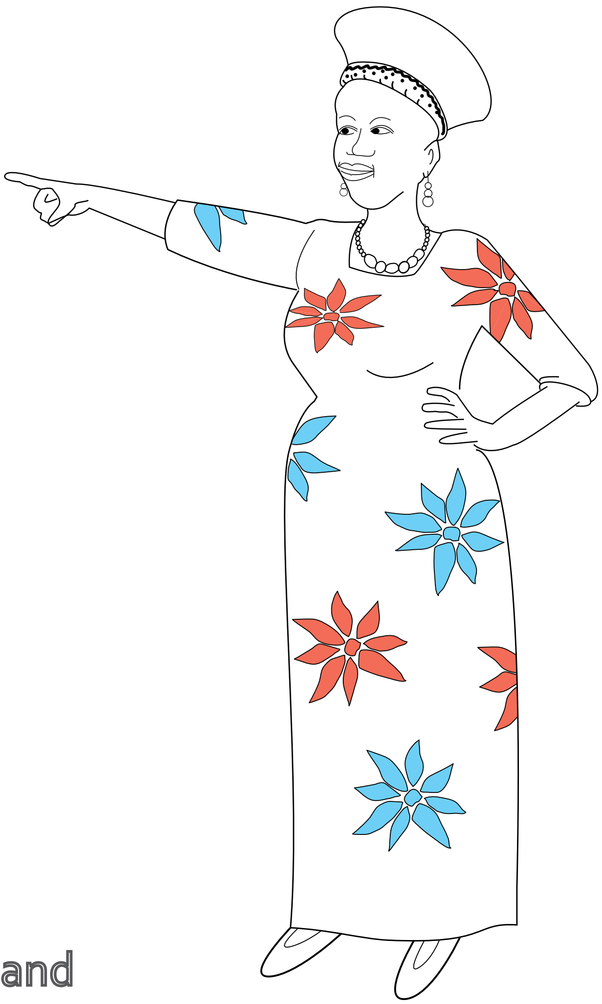
shaped in any way that suits your particular circumstances (e.g., a group of people could fill one role). We refer to the roles that make up this suggested GBPM team as **representatives** of their respective fields and/or skill-sets.

The first person you will want on your team is a spatial representative. This individual should be quite familiar with the landscapes in which you will be working. He/she should have knowledge of the accessibility of the landscapes (e.g., roads trails), be familiar with the daily and seasonal weather patterns in the area, and be familiar with its biophysical characteristics (e.g., topography, soils, hydrology, ecology, biodiversity). The spatial representative should also have access to quality regional maps.

The contributions of the **spatial representative** will be especially important in devising a sampling scheme for the area (Step 3). He/she will advise on the strengths and limitations of proposed sampling schemes for the landscape. This means identifying the feasible routes to take, the priority areas to capture subjects of interest, and the time of day and year to capture subjects of interest while avoiding predictable weather patterns that obstruct visibility.

The second person you will want on your team is a **land management project representative**. This individual should be familiar with the problems and land degradation present in the landscape and the sustainable land management projects or technologies that are being implemented. He/she should have knowledge of the objectives and intended or anticipated effects (e.g., biological, chemical, physical, social) that the projects





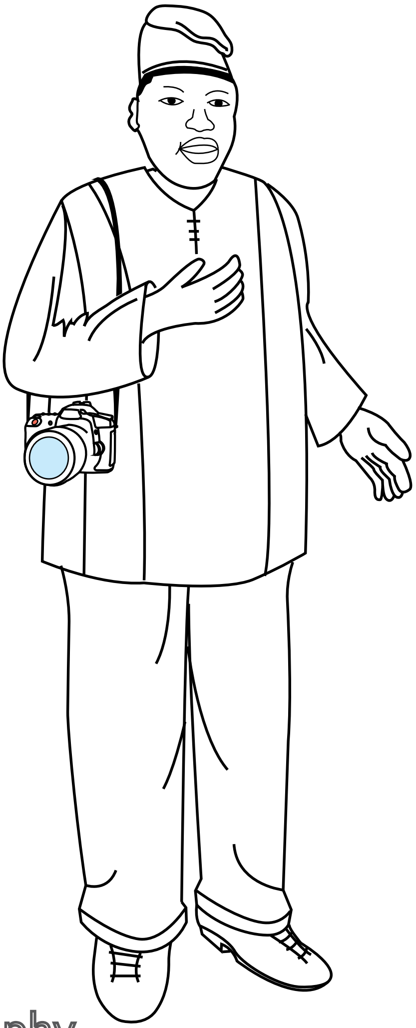
Land Management Project Representative

will have on the landscapes. In other words, the land management project representative should have a good idea of what success or failure might look like in the future.

The contributions of the land management project representative will be especially important in developing the analytical framework (Step 2), as he/she will help distinguish subjects of interest and drivers of change. He/she will also advise whether the proposed sampling scheme will effectively capture priority areas and subjects of interest. The representative may also contribute to the database management (Step 5) by tagging images and conducting and/or advising future analyses.

The third person you will want on your team is a **photography representative**. This individual should be familiar and competent with a digital camera, although this can be learned and is not a prerequisite. He/she should understand the basics of digital photography (e.g., exposure settings, image resolution, color models [RGB, CMYK], file compression) in order to advise the precision of analysis possible (see Appendix B: GBPM Equipment). The photography representative should also be able to take photographs and collect field data and/or facilitate community members in doing so.

The contributions of the photography representative will be important for several steps, but especially in developing the analytical framework (Step 2), devising the sampling scheme (Step 3), and field data collection (Step 4). He/she will advise whether a camera can capture proposed visual indicators in the analytical framework. He/she will also advise in the establishment of photo-points in the sampling scheme (e.g., identify future obstructions, visibility limitations). The quintessential role of the photography representative, of course, will be taking the photographs. And if community participation is desired, he/she will facilitate the process and ensure quality images with complete data are being collected.



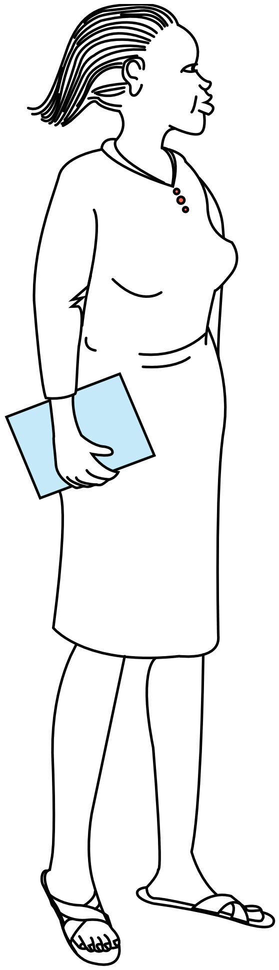
Photography Representative

The fourth person you will want on your team is a **database management representative**. This individual should be knowledgeable and competent with computers. He/she should be able to advise the use of and work with relevant software (e.g., GIS, Excel, Adobe Lightroom) in order to create a searchable image database (Step 5). He/she should be able to compile, organize, and back-up large amounts of data over time. Technology changes rapidly, especially with regards to data storage; since GBPM surveys have a long lifespan, the image database will need to be periodically updated. Hence, it is important that this representative be dedicated to the project or able to comprehensively transfer the responsibilities in the future.

The contributions of the database management representative will be especially important in the organization, storage, and analysis of images (Step 5), but they will also play important roles in the development of the analytical framework (Step 2) and data collection (Step 4). He/she will advise and keep track of the visual indicators developed in the analytical framework; compile all incoming data, either from the photography representative or community members; and ensure that the data collected at each photo-point is complete. It will also be his/her responsibility to create the architecture of the database in whichever software is selected (e.g., creating an attribute table in GIS, a spreadsheet in Excel) and tag the images with **keywords**. The database management representative may be responsible for future analyses or may simply be responsible for locating images and their databases when needed.

Again, the four representatives presented here can be mixed, matched, and shaped to fit your project and its particular needs and circumstances. Table 3 provides a summary of each team representative, their required skill-sets, and primary responsibilities.

The potential for community involvement exists within the roles of all four representatives, although certain roles may require some training. We especially encourage community involvement in the spatial representative role, as community members likely would be the most familiar with the landscape and would prove very helpful in locating (and re-locating) ideal photo-points. With a little training, community members also could easily and effectively contribute to the data collection process (i.e., photography representative), which could increase the chances of re-sampling photo-points at ideal times (e.g., immediately after a rain event). Moreover, community involvement in image pair analyses (i.e., among the database management representative) could facilitate any outreach and communication goals you may have; communicating the impacts of land management projects through photographs is an effective method when reaching across potential language, literacy, and/or education barriers. As you can see, the potential for community involvement is great and will depend on your creativity, willingness, and/or ability to provide basic training (as necessary), and, of course, the community's interest in participating. The focus questions on the next page will help you identify a GBPM team.



Database Management Representative

Action Points

- » Determine whether the division of four representatives is suitable to your project.
- » If not, decide how you will combine and/or divide these representatives.
- » Identify an individual or group of individuals for each representative.
- » Gauge their interest in and commitment to joining the GBPM team.
- » Identify what kinds of training they will need based on the qualities and skill sets discussed above.

Focus Questions

Who is willing, able, and interested in participating?

What knowledge base and skill-sets do you have available?

What equipment resources do you currently have (e.g. GIS, GPS, maps, cameras)?

How committed are participants? How long will they be around?

What do you need in a person and/or who would you need to recruit?

How do you want to integrate community involvement?

Should you establish a core GBPM team to oversee the project and serve as community liaisons for wider participation?

How should you divide up the representatives and responsibilities?

Step 2 • Analytical Framework: Defining GBPM Objectives

In this section you will:

Learn how to design a set of keywords that stem from project-based indicators of change that can be observed in photographs.

Learn about two case examples of different types of analytical frameworks for different scales.

As discussed earlier, the key characteristic that distinguishes a series of GBPM images from a collection of pictures is the analytical framework, which provides a programmatic context for interpreting observable changes in landscapes (large-scale) and/or study plots (small-scale). Since this framework is driven by the goals and objectives of the specific project or program, it is impossible to design a universal, one-size-fits all analytical framework. This means that a GBPM plan for an agroforestry project in the Central Highlands of Kenya will be quite different from one developed to monitor grassland restoration in Tanzania's Serengeti Plain. Being project-specific, the development of an analytical framework must involve ideas and contributions from your GBPM team and others.

The basic goal of an analytical framework is relatively simple: to design a set of keywords that stem from project-based indicators of change that can be visually observed in images taken over time (see Figure 8 and the "Keywords" box below) Images from your GBPM survey will be tagged with these keywords (Step 5), thereby enabling the creation of searchable database for quick image retrieval and analysis.

Keywords result from the consideration of various stages and aspects of the landscape in which you are working and your project's actions and objectives. These stages and aspects include: the baseline conditions of the landscape (i.e., at To), the "positive" and "negative" drivers of change within the landscape (i.e., the project's interventions and threats to the landscape, respectively), and the potential short- and long-term changes in the landscape. This step will involve consultation and investigation. Consult with your GBPM team, community members, and/or technical experts. Incorporate information from interviews with people affected by or involved with your project. Also examine project documents, progress reports, and other monitoring and evaluation materials to identify frequently used descriptive words or metrics.

About Keywords

Most modern digital cameras provide metadata associated with each image taken. In its simplest, this includes date and time, but more sophisticated cameras also provide camera, lens, and flash information; image size and resolution; and even longitude, latitude, and elevation. Image management systems employed for storing and processing images (discussed later in this manual) also allow image sorting and retrieval using these metadata. Tagging GBPM images with project-based keywords similarly allows users to sort and retrieve images within a GBPM database using these keywords. This may seem like an elaborate and unnecessary step, but consider that a long-term, multi-dimensional project might generate thousands of images over its lifespan.

Keywords can include the visual indicators identified as being critical to assessing the outcomes of project interventions. They can also include any relevant named landmarks, physical (e.g., mountains, rivers, settlement) or biological/ecological (e.g., agricultural lands, grazing lands, forests) features for landscape inventories, as well as inferential features that might be important in communication strategies or for retrieval (e.g., roads, power lines, permanent residences, commercial buildings). Keywords can be general (e.g., crop field, forest) and/or quite specific (maize field, miombo woodlands). As discussed in this section, their determination is project- specific and must arise from the consideration of project goals, objectives, and identified interventions. They should also represent key expected outcomes from the project.

You may find it helpful to categorize or tier your list of keywords. For instance, Franklin et al. (1981) identified three primary attributes of ecosystems for monitoring biodiversity in old-growth forests of the Pacific Northwest, USA: composition, structure, and function. In this case, composition referred to the identity and variety of elements, including species lists and species and genetic diversity. Structure referred to the physical organization or pattern of a system, such as habitat complexity. Function referred to the ecological and evolutionary processes, including disturbances and nutrient cycling. Noss (1990) also discussed the relevance of a nested hierarchy for

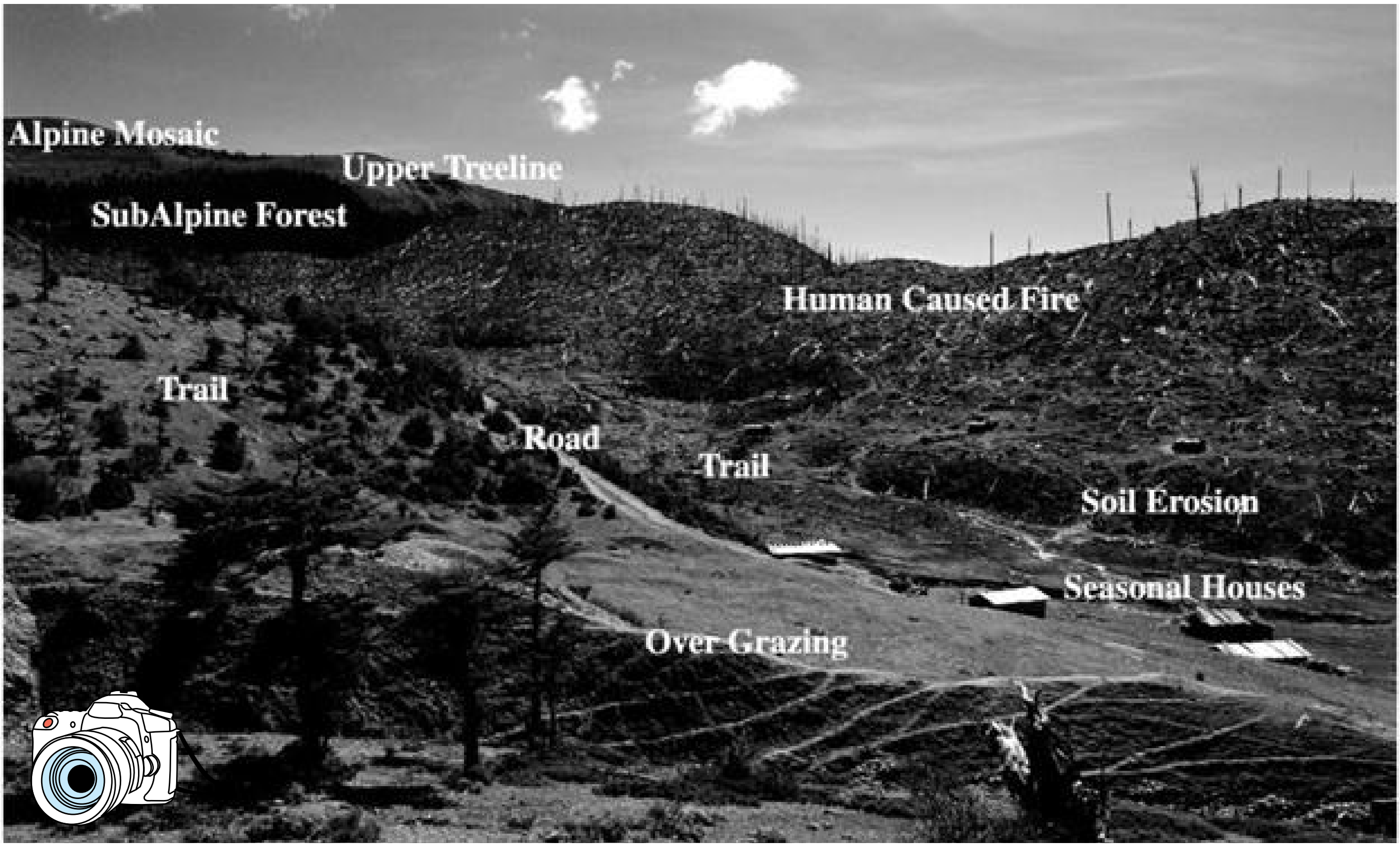


Figure 8. A GBPM Image in northwest Yunnan, keywords derived from an established analytical framework (from Lassoie et al., 2006).

biodiversity indicators, noting that biodiversity can be monitored at different levels of organization and spatial or temporal scales. While these papers addressed the monitoring of biodiversity only, the concept may prove helpful as you develop a set of keywords specific to your needs. Consider the differences and complementary nature of the physical, ecological, social, and/or economic aspects of your project's objectives.

Suggested Workflow

When designing your set of keywords, have your team discuss the terms used to visually describe the landscape (e.g., evergreen oak forest, gully erosion, Tsega micro-watershed) and terms used in other communication or progress reports (e.g., fuel wood harvesting, soil retention). Discuss the drivers of change in the landscape, both positive and negative. What will happen if the landscape is left unmanaged? Discuss your project's objectives and goals; describe your project interventions. Also discuss the anticipated effects of these interventions, both short- and long-term.

Keywords should be identifiable on a presence or absence basis; save the qualitative or quantitative verbs and adjectives (e.g., increased, improved) for later analyses. Compile the reoccurring, representative, and relevant terms from each of these discussions and descriptions into a preliminary keyword list. Remember that these keywords need to be visually recognizable from a photograph; review the list and remove or modify any abstract, qualitative, or quantitative terms. Figure 9 offers a suggested workflow for developing your list of keywords. Begin at the top oval and work clockwise. At each step, identify and compile keywords.

Brief Landscape-Scale Example

Recall from Part 2 the Target-Threat-Health combinations applied to the GBPM framework used by The Nature Conservancy (TNC) in China (see Table 2). We can see that project planning efforts had identified the Evergreen Oak Forest Type as being threatened by the over-harvesting of fuelwood, which was reducing the extent (size) and health (condition) of this important ecosystem. TNC implemented an alternative fuel project to address this issue, which intended to reduce the rate of forest clearing, improve/maintain the structural complexity of the forests, and lead to alternative, low impact means of fuelwood extraction (i.e., reduced erosion). Their GBPM sampling scheme developed a database of images in the project area at To to characterize the landscape status using the keywords

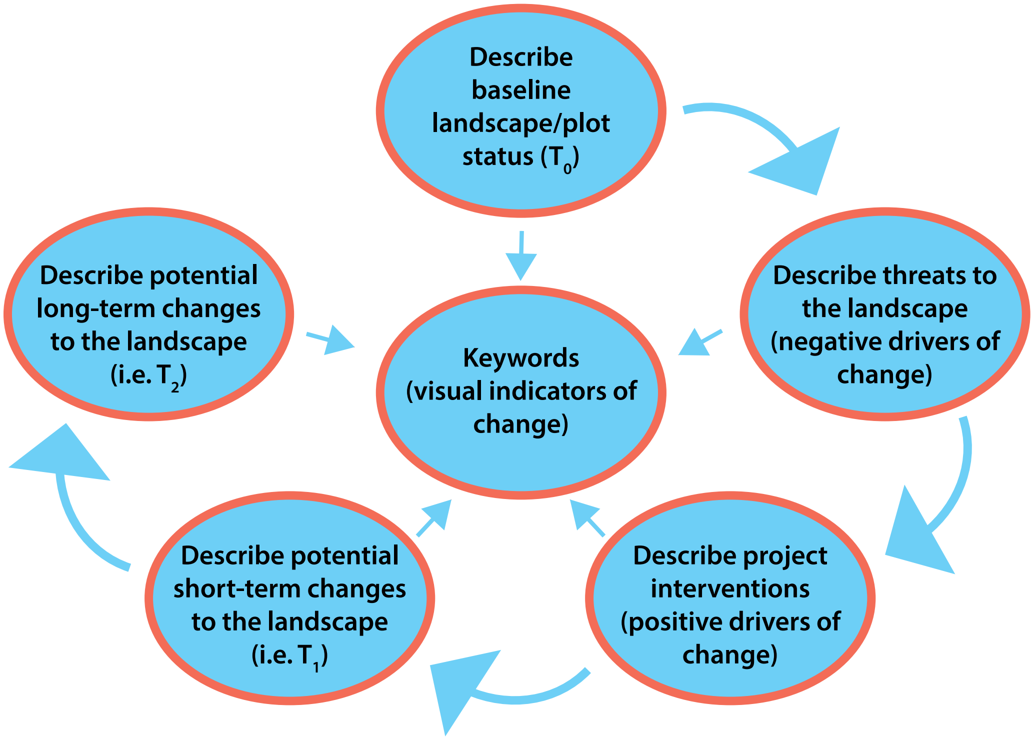


Figure 9. A suggested workflow for identifying keywords (i.e., visual indicators of change).

such as 'Evergreen Oak Forest' and 'fuelwood' as well as indicators of change using the keywords such as 'clearing', 'structural changes', and 'erosion'. Over time (i.e., at T1), the success of the alternative fuel intervention would be reinforced by observable decreases in clearing, increases in forest structure, and decreases in erosion. Most likely, these changes would be verified and reinforced with additional data from an alternative assessment tool, such as interviewing farmers and other fuelwood extractors and users.

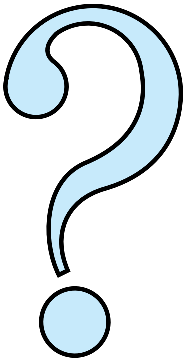
Brief Plot-Scale Example

The same process is used to identify keywords for small-scale projects. Consider the 27-year photo-monitoring study conducted Hall (2007) in Eastern Oregon. He selected four different plant communities as target sampling sites: ponderosa pine and pine-grass; ponderosa pine, bitterbrush, Idaho fescue savanna; low sagebrush and blue bunch wheatgrass; and rigid sagebrush scabland. These categories were used to target specific areas or plots for photo-points. Permanent photo-points were established at each site and photographs were taken at close range utilizing a meter stick as a point of reference. As Hall was looking specifically at the production of shrub and herb cover on these sites, his list of keywords was more specific and included mostly plant species (e.g., Poa scunda and Arnica cordifolia). Hall's precision in re-sampling the photo-points permitted careful scrutiny of the images, which yielded recordable effects such as seed head counts for different species and percent species composition.

A set of focus questions to help you establish an effective analytical framework are in the box on the following page.

Action Points

- Based on your established project goals and objectives identify critical aspects of the landscape/plots that you anticipate will change over the lifespan of your project.
- Assess the threats and your interventions as being drivers of change.
- Consider the short- and long-term effects of your project.
- Develop a comprehensive set of visual indicators of these innovations and the changes in landscape/plot status that can be expressed as keywords.



Focus Questions

What is important for future communication of these projects? What terms are used in progress reports or justification for further investment?

What do the landscapes in question look like now? Consider:

a. Land use classification terminology

b. Composition: general (ecosystem-level), specific (species-level)

c. Differences in climate, soil types, and/or biodiversity?

d. Landmark names, reoccurring features (e.g., mountain, field)

e. Functions (e.g., water filtration, nutrient cycling)

f. Human factors (e.g., land ownership, population densities)

g. Degree of degradation (e.g., severe, moderate, low, none)

What are the threats to the landscape (i.e., negative drivers of change)?

What land management projects are being implemented? Describe the technologies and implementation process.

What are the anticipated changes? Consider:

a. The different categories of impact (e.g., social, ecological, economic)?

b. What are the short-term goals?

c. What are the long-term goals?

Compile your list. Consider:

a. What are reoccurring terms?

b. Which are visibly observable and relevant?

c. Are there tiers or priorities?

d. What aspects of this analytical framework are most important for us to capture?

Step 3 ◦ Sampling Design: Selecting Representative GBPM Photo-points

In this section you will:

Learn how to develop a sampling strategy for establishing photo-points that is consistent with your analytical framework, the topography, and the intended uses for the GBPM system.

As discussed earlier, a major shortcoming of all historical repeat photography studies that track landscape change is that they relied on old photographs to establish initial conditions (i.e., designated as T_h). Oftentimes these photographs were taken at the whims of the earlier photographers and/or were meant to highlight certain features of a landscape that may not be of interest to the GBPM team. Hence, their relevance to current conditions might be greatly biased, as they certainly do not provide a comprehensive and systematic coverage of the landscape. A **forward-sampling** GBPM design eliminates this limitation by purposefully sampling the landscapes or study plots using a predetermined sampling method. Devising such a strategy involves spatial, temporal, and frequency considerations, which are tempered by limitations in access, time, money, and personnel.

Just as the analytical framework is unique to each GBPM system, so too is its sampling method. There are several ways in which you can structure your sampling method to accommodate some of the limitations mentioned above. However, depending on the objectives and goals of your project, different sampling methods can add to or detract from the overall interpretations that can be made. Hence, it is important for the sampling methodology to mesh seamlessly with your project's objectives. The most important thing to remember is that the method should be consistently followed throughout the entire project (i.e., at T_0, T_1, T_2, etc.).

Spatial Considerations

Four methods for sampling an area or landscape and the strengths and weaknesses of each when applied to GBPM systems are listed below. Consider your project's objectives and limitations in order to select the most appropriate sampling strategy. It is possible to use a mixture of sampling strategies depending on the specifics of the project. However, it is critical to maintain consistency with your method when you sample (i.e., photograph) your landscape.

Random sampling entails randomly selecting photo-points before going to the field and then precisely locating those points in the landscape. Considering its strengths, it is the preferred method for many scientific studies because of the statistical possibilities that such a design allows. Random sampling also offers a distinct advantage if one is focused on addressing variation across relatively uniform landscapes (e.g., vegetation status of a Kenyan miombo woodland or the Tanzanian Serengeti Plain).

However, random sampling poses distinct challenges and disadvantages in many landscapes. First, in areas that are extensively privatized, topographically extreme, or otherwise relatively restricted for access (e.g., militarized zones, protected areas, industrial sites), traveling to predetermined photo-points can be difficult if not impossible. Hence, access within your landscape is a definite weakness that you must consider before selecting this sampling method. Second, since the photo-points are determined randomly some landscape features might not be sampled simply because of chance. This can be critical in diverse landscapes where certain important features (e.g., wetlands) might represent a relatively small percentage of the entire area. Of course, this weakness can be minimized by increasing the sample size, but this also increases the time and cost associated with the sampling process.

Opportunistic sampling entails the selection of photo-points based on the ease of accessibility. Photo-points can be randomly determined along transects that traverse the landscape, where photo-points are established at predetermined intervals (e.g., 5 m, 100 m, 1 km). Although this approach may allow for statistical analyses, it also suffers from the same limitations as random sampling. Often transects are established using roads, rail tracks, footpaths, river shores, or tree lines that provide relatively easy access to the landscapes. Certain features may not be represented either by chance or because of their distance from the accessible routes or transects. Photo-points can be established at fixed intervals or at locations of specific interest to the project (e.g., wetlands).

Quota sampling entails the selection of photo-points from mutually exclusive sub-groups at a certain proportion (e.g., 10 wetlands, 10 rivers). These sub-groups can be determined based on the geographic divisions in your landscape, such as micro-watersheds or villages, or based on particular features or project interventions that you wish to monitor, such as gullies or plantation sites. The number of photo-points to sample, or a quota, is then determined for each sub-group, independent of the entire landscape's actual characteristics. Quota sampling is advantageous in that you can ensure particular features or interventions are sampled sufficiently. Quota sampling is quite flexible and can overcome many access, time, or resource limitations you might face. You can identify ideal sites for each sub-group before venturing into the field or establish photo-points wherever the opportunity exists until you have reached the set quota. However, because of this flexibility, quota-sampling is non-representative and so it is best to abandon statistical ambitions for generating conclusions about the landscape in its entirety.

Strategic sampling entails the selection of photo-points based on their likelihood of potential change or the presence of specific focal points as outlined in the analytical framework. This is a modification of opportunistic sampling where accessible photo-points are established for their content relative to project objectives. Strategic sampling is an obvious strategy for plot-level projects and depending upon the study design, statistical testing of changes over time might be possible. For example, one could monitor and compare relative corn growth over a growing season in response to the addition of green manure.

When using this flexible sampling strategy, photo-points can be identified on maps or with other geo-referencing material prior to fieldwork. Of course, additional photo-points can also be established while in the field in response to unforeseen opportunities. Because of the specific nature of this sampling strategy it is critical to involve a project team member who is knowledgeable of the entire project and familiar with the diversity of features across the landscape. Figure 10 illustrates a sample of photo-points established in Tigray, Ethiopia.

When applying strategic sampling at the landscape level (i.e., large-scale), it is best to abandon the use of rigorous statistical testing. Although testing can be developed at an experimental level, it is far beyond the functionality of the GBPM methodology under most operational conditions, and much better approaches exist if such quantification is critical (e.g., GIS). Hence, it is important not to ask too much from the GBPM of landscapes and to recognize that strategic sampling has proven extremely useful in qualitative, long-term analyses of landscape changes (see Appendix A: Annotated Bibliography).

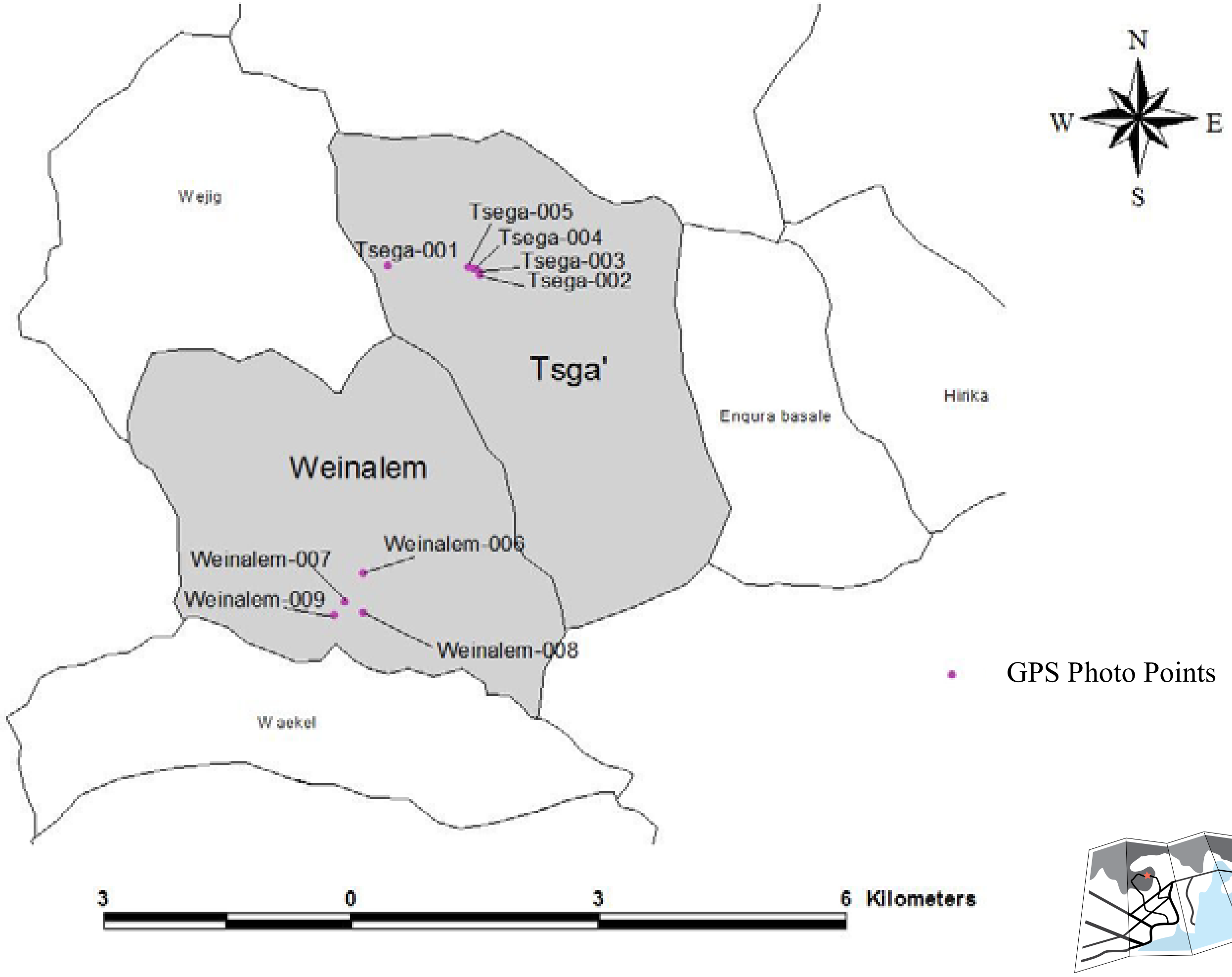


Figure 10. Map depicting sampled photo-points established in Tigray, Ethiopia.

Temporal Considerations

Timing must be considered when devising your sampling scheme as conditions often arise that greatly limit the visibility of landscape features in your resulting images. For instance, clear skies are vital for photographing broad landscapes, especially when photographs are taken from a considerable distance. In contrast, clear conditions are less important for monitoring plot-level projects. Light conditions fluctuate predictably on daily and seasonal cycles, but are greatly modified by local weather conditions. In addition, if central aspects of a project address either natural or agricultural vegetation, as do most conservation and ecoagricultural projects, then the seasonality of plant growth and life-cycles must be considered.

Unfortunately, these temporal realities sometimes combine in unpredictable ways to cause insurmountable problems. For example, photo-monitoring provided limited support for an integrated ecological-sociological study of alpine meadows in Northwest Yunnan, China (Lassoie and Sherman, 2010). The monsoonal weather pattern that characterizes this mountainous region means that the growing season is marked by warm, cloudy, and wet conditions while clear conditions, which are excellent for photo-monitoring, occur in the autumn and winter. Hence, it is critical that you address the following temporal considerations relative to your specific project area.

The **time of day** affects the angle, quantity (intensity) and quality (wavelength) of light reaching the Earth's surface, which change greatly throughout the day even under clear sky conditions. The angle of bright sun can cast strong shadows on the landscape, making it very challenging to capture an image in which the light-dark contrast is not too strong. The quantity and quality of light as well as the clarity of the air will be greatly influenced by atmospheric conditions. Many regions can be marked by the build-up of hazy conditions during the day caused by either dust (dry areas) or moisture (wet areas) in the air, leading to flat, featureless images. Other regions are prone to morning fog, which can completely eliminate visibility. Bright, overcast days with high clouds are often ideal, as they provide even lighting without harsh shadows.

While it is ideal to sample photo-points at a time of day with the best light and sky conditions—typically morning or evening—you will need to take into consideration the limitations you face. For instance, limited access to a landscape may increase the time it takes to reach a given photo-point and the costs associated with such transport may necessitate the consolidation of sampling to one or a few days. This will result in some photo-points being sampled in the middle of the day when the sun is at its peak and shadows are harsh. If this is the case, consider planning your sampling route so that close range, plot level photographs are taken at the height of the day and long-distance, landscape level photographs are taken during the morning or evening hours.

While the **time of year** greatly affects light quantity, quality, and day length, this effect decreases with latitude. However, seasonal weather patterns can be very influential and may be pivotal in regions near the equator. Seasons marked by rainy, misty, and/or overcast conditions (e.g., monsoons) will greatly limit visibility and image quality, and will likely need to be avoided, if possible. Such weather can also limit access to photo-points within certain landscapes. Thus, times of year when visibility is the best and road conditions or accessibility routes are navigable are preferred to ensure that the most information can be acquired from the GBPM survey. However, as discussed earlier, such timing needs to be adjusted to match critical programmatic elements, such as the growing season or harvest period for agricultural projects.

Frequency Considerations

So far, we have been rather vague with respect to the sampling frequency for a GBPM survey. At the beginning of a project you will need to establish a baseline (T_0), and accumulate any available and usable historical photographs (Th), if desired. If possible, you can gain a unique baseline perspective of your project area through a historical comparison (i.e., T_h vs. T_0), but the value of GBPM will be realized by designing a **forward-sampling** strategy. Hence, you will need to determine the re-sampling intervals to be used after the baseline has been established.

Frequency considerations are important to consider prior to starting your survey, as the comparability of the resulting images (e.g., T_0 vs T_1 vs T_2, etc.) is dependent on consistent re-sampling. If you return to the field to re-sample photo-points whenever you have the time it will become increasingly difficult to distinguish between changes resulting from your project's interventions and changes resulting from external effects, such as daily or seasonal environmental fluctuations. For example, two images compared side-by-side may suggest a visible increase in water availability. However, if one image was taken during the dry season and the other during the rainy season, you cannot determine whether the result was an effect of a newly established diversion channel or merely a recent rain event.

The frequency of re-sampling depends completely on what is being monitored. The key is to identify how fast the anticipated changes will occur in the landscape in response to your interventions. Do you anticipate that results will be visible within a year or by the end of a five-year project? Or perhaps the potential changes you are monitoring will manifest gradually at different stages (i.e., short- and long-term changes). For example, the results of tree-planting, agricultural modification, or stream bank restoration might be easily assessed a year after implementation, while an alternative energy project might take a decade to influence deforestation rates.

Other aspects to consider when determining the frequency of your sampling method are your time, transportation, and personnel limitations. That is, will your GBPM team and/or your photographer(s) be able to visit the landscape and re-sample photo-points regularly? If you will be depending on one or a few photographers to sample your landscape, consider how often they will be able to devote the time and energy necessary. A land management advisor who has many other responsibilities at any given time may not be able to re-sample every year. If you will be relying on community members to sample photo-points, consider their willingness to consistently re-photograph those points. Often this will depend on other demands on their time.

It may be impossible for you to re-sample at exactly the same time as your baseline sample (i.e., T_0) and you might be forced to re-sample photo-points whenever possible. If this is the case, be mindful that every hour or day that stands between your baseline and your next repeat image can detract from the comparability of those images.

Suggested Workflow

Below is a suggested workflow for developing your sampling method (see Figure 11). As discussed earlier, it is important to consider the spatial, temporal, and frequency contexts of your project and the landscape in which you will be working. As the GBPM sampling method is unique to each project, it will be helpful to consult with your GBPM team and any individuals who will be involved in the data collection (e.g., community members who will be taking pictures, providing transportation and/or serving as field guides). The focus questions below should be discussed with your GBPM team when identifying an appropriate sampling scheme.

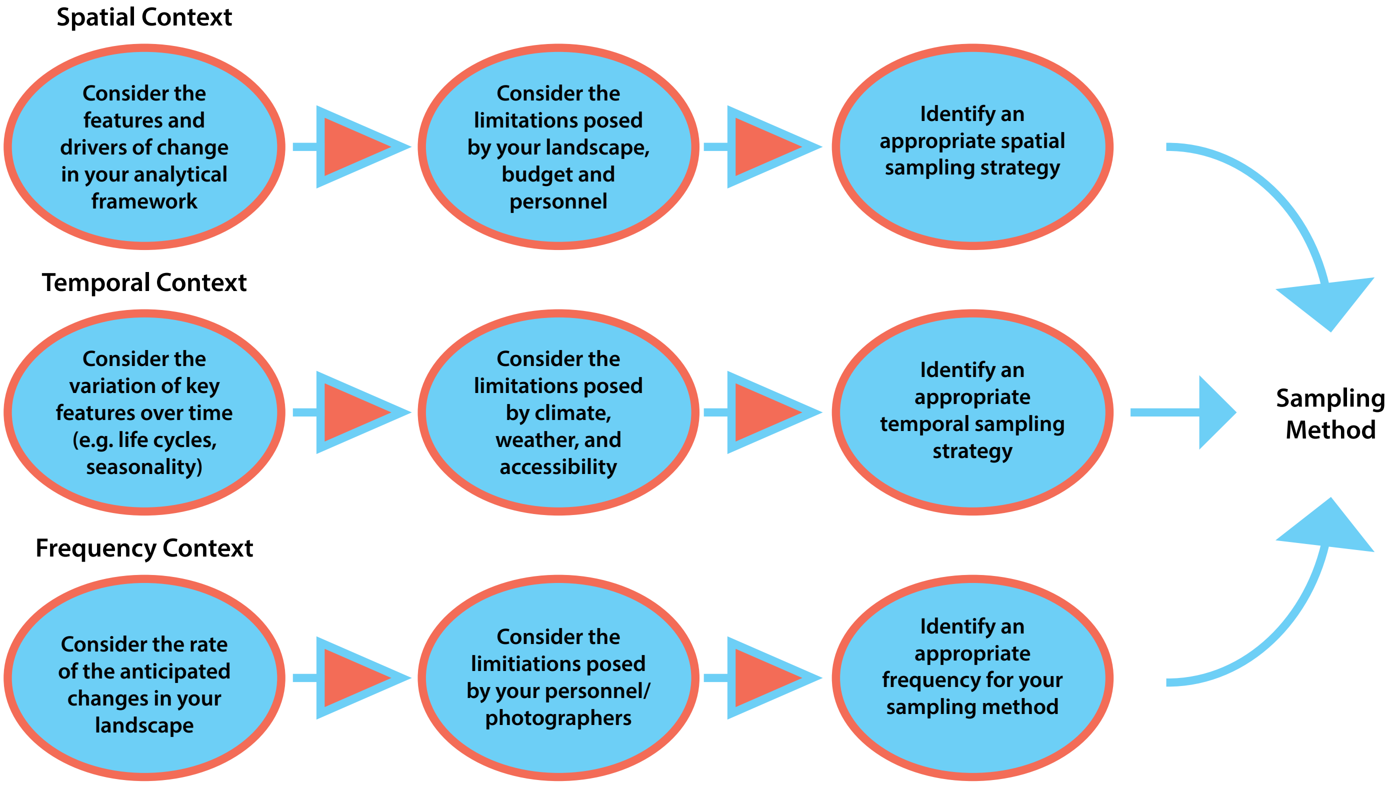
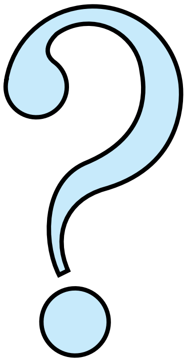


Figure 11. A suggested workflow for devising a sampling method considering the spatial, temporal, and frequency contexts of the project.

Action Points

- Develop a spatial sampling scheme that meets the needs of your project and the conditions of the project area.
- Develop a temporal sampling scheme, both the season(s) and time(s) of day.
- Determine the frequency of your sampling scheme to align with landscape/plot status changes you expect.
- Compile this information and design your appropriate sampling strategy.

Focus Questions



Looking back at your analytical framework, what features or drivers of change are you most interested in monitoring and what changes do you anticipate?

What limitations exist within the landscape (e.g., topography, accessibility, visibility)?

What will be the ideal spatial sampling strategy (e.g., random, opportunistic, quota, strategic, or a combination)?

What predictable fluctuations exist in weather, daylight, and/or life cycles and how do they affect the features of interest, drivers of change, or visibility for taking photographs?

What fluctuations exist within a day (e.g., fog, haze) and how might they affect visibility for taking photographs?

What will be the ideal time to sample and will that be possible given the limitations?

What is the timeline of change for your project interventions?

What is the ideal frequency for re-sampling photo-points and will consistency be possible given the limitations? If not, how will that limit future comparisons?

Step 4 • Field Implementation: Photographing the Landscape or Plot

In this section you will:

Learn how to create a naming system and datasheet.

Learn how to establish photo-points and collect important data at each point.

Learn how to re-sample photo-points.

Materials List

- ✓ Digital camera
- ✓ Memory card
- ✓ GPS
- ✓ Map of the landscape
- ✓ Datasheets or a logbook
- ✓ Prints of historical photographs (T_h) if being used
- ✓ Pencil
- ✓ Compass, tripod and bubble level (optional but recommended)

The crucial step in this GBPM methodology is, of course, taking the pictures (i.e., collecting data). This step can vary depending on the resources you have available and the level of precision you want to achieve. For instance, using a suite of instruments including a GPS, tripod, compass, and high-end digital single lens reflex camera, will result in precise documentation of each photograph thereby enabling accurate repeats in the future. Additionally, the more exact the timing and composition of the repeat photograph, the more information you can extract from any comparison with an earlier image. However, the equipment can be costly and technically difficult to master. By contrast, using a simple cell-phone camera might be sufficient for yielding insightful comparisons in future analyses. However, replication of images in the future can prove difficult with basic, automatic digital cameras, thereby detracting from the clarity and depth of the image comparison.

We will introduce the data collection process for establishing GBPM photo-points using standard equipment that you likely already have in your office. Modifications of this process are possible if other resources are available (see Appendix B: GBPM Equipment). We start with the materials and equipment needed for establishing a GBPM survey and will later move into the process of data collection.

Materials and Equipment

A basic **point-and-shoot camera** is a great tool to use and as time goes by, the image quality from these kinds of cameras is improving greatly. Be cautious that you do not zoom the camera, especially beyond the optical zoom (i.e., digital zoom), as it will be very difficult to replicate the frame in the future and digital zoom detract greatly from image resolution (i.e., quality).

You will need a **memory card** for any kind of digital camera. Most often point-and-shoot cameras require SD cards, but refer to your camera's manual for more information. Ensure that you have enough memory on the card for a full day's data collection.

A **handheld GPS device** is important for recording locations within your landscape for database reference and returning to the sample point at a later time. Any handheld GPS will do. It's unlikely that your GPS device will pinpoint your position exactly, especially when you are sampling in places with potential signal interference such as under a forest canopy or in a deep valley. It will however, give you a general location to return to, after which the photo-point description you record in your datasheet (see below) will help you return to the exact position.

A **map of the landscape** can be used as a secondary geographic reference and can occasionally be more reliable than a GPS device. If you do not have access to a GPS device you can use a map in its place. Large-scale, topographic maps with recognizable landmarks or routes (e.g., mountains, villages, roads) are best as they are easier to pinpoint your location while in the field. If possible, you will want a large, printed map so that you can mark all of your photo-points on one map.

Datasheets or a data logbook is critical for recording other data at your photo-point, such as weather conditions, photo-point descriptions, and filenames. You can create a template at your office and print copies to take into the field or replicate a standard format in a notebook. It is important to develop a standardized format for recording data and it is helpful to keep all of your data within one notebook or binder. Keep in mind that you can never record too much information, as details will be important when you return to the information after a week, month, or year. Do not rely on your memory!

If you will be using **historical photographs** for a baseline (Th) or you will be re-sampling (T1) initially established photo-points (T0), you will need to bring printed copies of these photographs into the field with you. These are important for re-locating the position of the camera and replicating the frame as close as possible. These are especially important if you do not use other precision equipment such as a compass or GPS. Black-and-white prints on standard office paper are fine; just make sure that the print's contrast is not too strong and that some key features are recognizable in the photograph (e.g., river banks, large trees, outcroppings, landscape horizons).

Additional equipment can improve your precision and accuracy. A **compass** along with a good map will help locate you within a landscape. A camera **tripod** will hold the camera steady at slow shutter speeds (necessary in low light conditions) and will help you accurately frame the image (especially useful in re-sampling). A **bubble level** will also help frame images. Appendix B: GBPM Equipment provides more detailed information about other types of equipment and their differences in quality relative to GBPM surveys.

Creating a Naming System

Naming systems become important when you begin to acquire large amounts of data. Design and begin using such a system immediately as you will quickly accumulate hundreds of images. You can develop naming systems for the photo-points, the photographs themselves, or both. Naming systems can be very simple to complex codes that take into consideration some or all of the following: location, date, repeat frequency, camera type, photo-point number, and image number. You will want to create a naming system that makes sense to you and has all of the relevant information you think is necessary. At the very least, it is helpful to name the photo-points. You can name them sequentially (e.g., 001, 002, 003) or categorically (e.g., Tsega-001, Weinalem-004). Use padded zeros if you anticipate lots of photo-points (e.g., Tsega-00001).

Image Coding

Sample Image Code: T00-052110-003-04

T00: T stands for time and the number stands for the sequence the image was taken in the survey. In other words, T00 stands for Time Zero (T0) or the first set of images taken in the survey. Retakes of images at the photo-point into the future would therefore be noted as T01, T02, T03 and so on.

052110: This number is shorthand for the date the image was taken (month, day, year): May 21, 2010.

003: This number is the photo-point number within the entire survey.

004: This number stands for the image number within the photo-point set. In this example, this indicates the 4th image taken at photo-point 003.

Whichever naming system you choose, it is helpful to have a basic explanation of your code system (see below) saved in a text document wherever your files are stored. The following box shows a sample naming system with an explanation of each component of the code.

Creating a Datasheet or Logbook Format

Recall from Part 2 the datasheet that Hall (2002) created for use in the field (see Figure 6). You will need to create a similar template or basic format for your logbook to ensure that you record such information at each photo-point and sampling date. If your camera records the date and time and you have successfully set the internal clock, you may exclude the date and time from your datasheet and simply reference the metadata when you return to the office. However, it may be easier and more reliable to simply record this information while in the field. Consider the example below when developing your datasheet template.

Date and Time: January 10, 2014; 3:15pm

Photographer: Mehbrahatom Fekadw, GIZ M&E Advisor

Photopoint Name: Tsega-001

Location Description: Kase, above gully, looking East

GPS Coordinates: S 12° 26' 14.5" E 32° 21' 32.8"

Weather Conditions: Hot, dry, hazy, no clouds

Field Notes: Mountain in middle-ground ~70% slope, *Shilen* trees

Photo Name	*Photo Filename*	*Compass Direction*
T00-140111-001-001	BON_0048.jpg	130°
T00-140111-001-002	BON_0049.jpg	165°
T00-140111-001-003	BON_0050.jpg	192°

Establishing a Photo-point

First, if you are using a GPS, allow the unit to begin measuring its location (this can take several minutes). Locate where you are on your printed map and make a small mark with your pencil to indicate that you are establishing a new photo-point at this location. Create a name for your photo-point using the naming system you created and note it on the map. Fill in your datasheet or logbook with relevant information, such as the name of the photo-point, the weather conditions, and a brief description of where you are.

Taking the Images

To take the image, hold the camera up to eye or shoulder level. Hold your arms against your side to steady the camera and reduce the amount of vibration during the exposure; any shaking when the camera is taking the photo will cause the image to be blurry. Hence, the use of a tripod is often preferable. Use the viewfinder or display screen to frame the landscape so that the horizon is level or parallel to the frame and that the majority of image is composed of land, not sky (a bubble level can help). Try to avoid cutting off important features or parts of features within the frame.

One or many images can be taken at each photo-point, depending on the size of the area and the level of detail you wish to record. You may find that one or two images at each photo-point will suffice. For wide landscapes or large areas, however, you may find a panorama (a sequential series of images connected together using imaging software) to be ideal. A comprehensive view of an open landscape might entail a 360° panorama, whereas a vista with a mountain or forest obstructing a portion of your view will only need a 180° panorama.

The most important step in capturing a panorama is to overlap a portion of the frame in each consecutive image. A good rule of thumb is to overlap at least 20% of the previous frame. To do this, it is best to choose a landmark or noticeable physical object on the edge of the frame in the first image and then realign the next image so that the same object is in the opposite side of the frame (see Figure 12). For example, if the image capture direction is clockwise, one would choose an object on the right side of the frame like a house or a recognizable hilltop, then for the next image the object will be clearly visible on the left side of the frame.

Images can be consecutively captured from right to left (counter-clockwise) or left to right (clockwise). Whichever direction you choose should be repeated throughout the survey in the present (T_0) and into the future (T_1, T_2, T_3, etc.). It is especially helpful when taking panoramas to record the azimuth direction of each image on your datasheet using a compass.

When capturing images at your photo-point there are two manual camera settings that we encourage you to familiarize yourself with and use where possible: ISO and aperture. **ISO** refers to the sensitivity of the digital light sensor in the camera. A high ISO value corresponds to a high sensitivity to light and vice versa. In a low-light situation, such as morning or evening, you may need to set your camera to a high ISO in order to obtain an adequate exposure whereas during mid-day a low ISO will be sufficient. However, in some cameras a high ISO (e.g., 800-1600+) may introduce noise thereby reducing the image's clarity. Hence, we recommend image capture with a low ISO value whenever possible. Refer to your camera's manual to determine how to adjust your ISO.

Aperture is a measure of the opening in a lens through which light passes. Aperture directly affects the depth-of-field of an image, which refers to the section of the image that will be in focus (i.e., foreground, background, or both).

Figure 12. Two consecutive images in a panorama that depict a recognizable tree for aid in overlap.

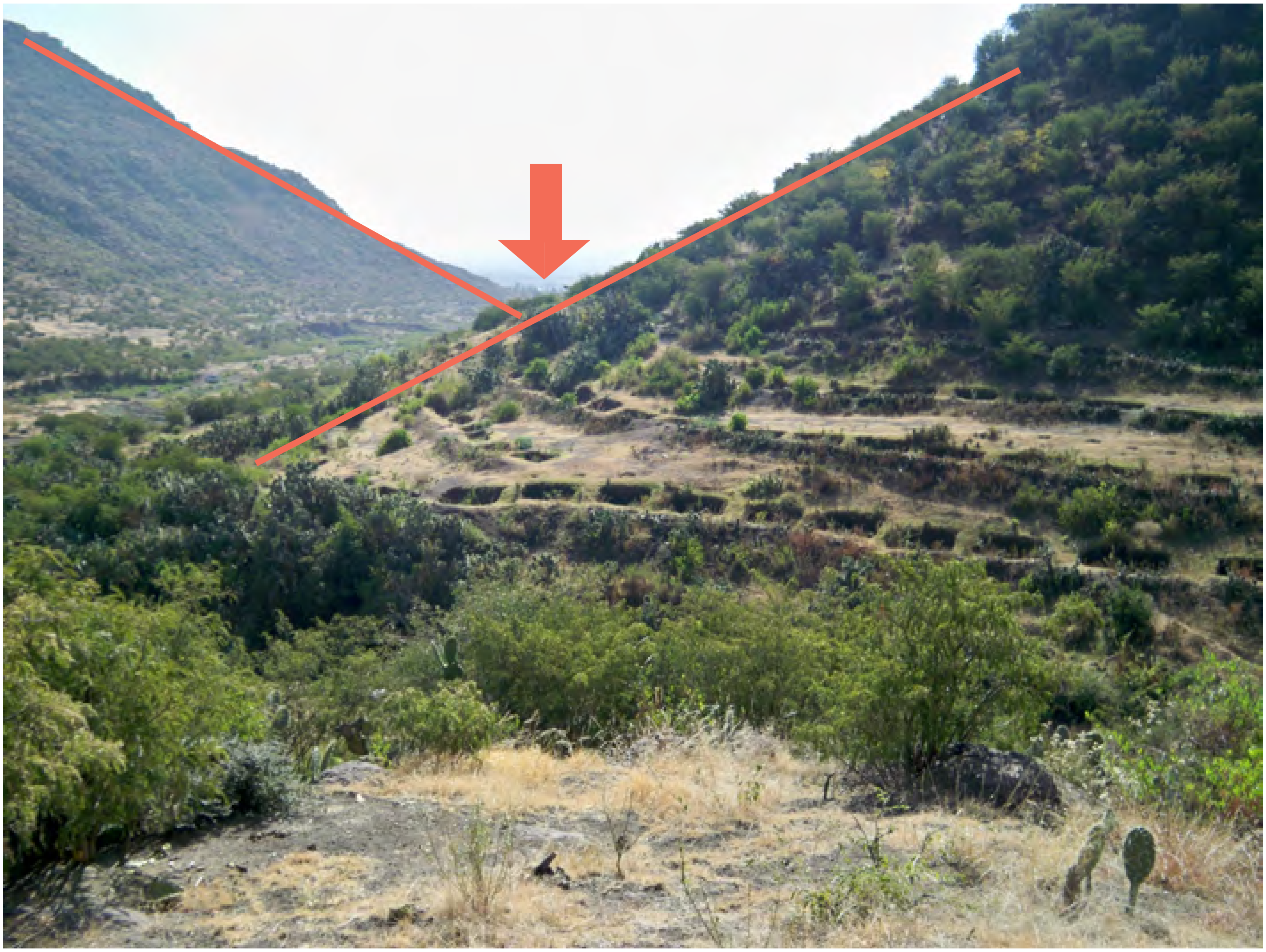


Figure 13. An image from a photo-point in the Tsega micro-watershed in Southern Tigray, Ethiopia. The red arrow points to a distinguishing convergence of two hillsides while the two red lines accentuate the two slopes of the hillsides.

Optically, a wide opening (a low aperture value) will result in a low depth-of-field so that only a narrow section of your image will be in focus (e.g. foreground). A small opening (a high aperture value) will result in a high depth-of-field so that both the foreground and background will be in focus. However, similar to ISO sensitivity, in low-light situations a high aperture may not be possible. For GBPM image analysis, a high depth-of-field is ideal hence we recommend a high aperture value whenever possible. See Appendix B: GBPM Equipment, for more details on ISO and aperture.

When using a compass, hold it flat on your palm at waist height and adjust the wheel to determine the azimuth direction in which the image was taken. You can use magnetic or true North depending on the magnetic declination in your region (see www.ngdc.noaa.gov/geomag-web/). In either case remain consistent and make a note of whichever North you are using on your datasheet.

Record the filename and compass direction for each image on your datasheet. You can find the filenames by reviewing the image and its metadata on your camera (refer to your camera manual for specific instructions).

Lastly, when the coordinates have stabilized on your GPS device, title and save your location as a **waypoint** and record the coordinates on your datasheet. You may want to make a note of which grid system you are using (e.g., UTM).

Once all the images have been taken at the photo-point move onto your next one and repeat the steps above.

Re-Sampling an Existing Photo-point

Depending on the time interval defined in your sampling scheme, you will eventually be re-sampling your photo-points (T_1) instead of establishing new ones. At such time you will need printed copies of your images and datasheet

Figure 14. A scan of a historical image of the same photopoint as Figure 13.

or logbook for each photo-point from To in addition to the equipment identified earlier.

The first step is to relocate your photo-point within the landscape. If you used a GPS to mark the location when establishing the photo-point, find its waypoint on the GPS device and navigate to that location. If you used a map and compass, use recognizable landmarks and routes to relocate the photo-point. Once you are in the general area of a photo-point, you might remember where you were standing and which direction you were facing when you took the original image(s); if not, refer to your location description and/or compass direction that you recorded earlier to pinpoint exactly where you were standing. Note that landmarks such as boulders may have shifted slightly and trees and other vegetation may have grown larger.

Once you are confident that you are in the same location, use a printed copy of your To image to precisely align the camera so to frame the T_1 image in the same position. If you used a compass when establishing the original photo-point, identifying the precise direction for taking another image will be relatively easy. If not, you should be able to align the frame using the following method.

First, identify a few major landmarks or distinguishing features in the **background** of the image (see Figure 13). Large, relatively unchanging topographical features are best, such as converging mountain slopes and hillsides or valleys, but these features may also include rivers or fields. Be aware that certain features, like forest or field boundaries and even river shapes may have changed over time. Hold up the original image at eye level and move yourself to a position where the background features in the image and landscape are identical.

Next, identify a few minor landmarks or distinguishing features in the **foreground** or **middle-ground** of your image. Depending on the time elapsed since the last image was taken these features could include distinguishing trees, shrubs, and boulders, or rivers, gullies, or land management interventions, such as terraces and trenches. Be aware that certain features may have changed or moved. Hold up the image at eye level and move yourself to the position where the foreground or middle-ground features in the image and landscape are identical.

When both the background and foreground or middle-ground features are aligned, you should now be able to re-photograph the landscape (T_1) with a near identical frame as the original photo-point (T_0). Ensure any manual camera settings are optimal, such as ISO and aperture (see above). Hold up the camera at eye or shoulder level and take your image. Repeat the above steps for each image captured at this photo-point. On a new datasheet or page in your data logbook, again record the name of the photo-point, date, and time, photographer, weather conditions, and other field notes. Record the image filename just captured. If the conditions of your photo-point location have changed (e.g., new trees, landmarks have moved), it may be helpful to revise the location description to assist in the next re-sampling (T_2). It is not necessary to record the GPS coordinates of the re-sampled photo-point or the compass direction(s) of the image(s) as these likely will not change between T_0 and T_2. Move on to your next photo-point and repeat the above steps.

Step 5 • Organizing, Storing, and Analyzing Images

In this section you will:

Learn about the many options available to customize a photo database and analyze your photographs.

Learn about archival techniques that will make your photo database a durable resource for your project and for other researchers well into the future.

Learn how to upload, tag and analyze your images within a database.

When you have finished data collection in the field, it is best to upload the data as soon as possible to avoid confusion and possibly losing any data. Uploading the data into an organized image database requires a technical understanding and proficiency with the system used. For example, using a basic data table and filing system (e.g., Microsoft Excel and image folders) requires less technical mastery than using a GIS.

A technical understanding of database archival is also necessary. Some examples of current archival formats include: writable CD-roms, external hard-drives, and online storage systems. As technology changes rapidly, an ability to update or renew the archival system is also important. You will need to select whichever format is available to you and easiest to integrate into your existing office workflow. This may change in the future as certain resources or systems are developed.

We will briefly discuss some options for organizing, storing, and archiving your database. We will then discuss the process of uploading and tagging images in your database and how to search and perform analyses in the future.

Image Database Systems

Microsoft Excel is a good system for database management in that people in your organization are likely comfortable working with it and most computers will have it already installed. You can use the same template or format used in your datasheet or logbook in Excel. You can also download your GPS data into an Excel spreadsheet directly. Its weakness is that it is difficult to integrate all of your files and data into an Excel spreadsheet. As such, you will need to maintain a separate organized filing system for images and maps.

GIS is a powerful tool for creating an image database that incorporates all of your data into one system. An attribute table can be created similar to your datasheet or logbook, and image files and GPS data can be linked to the database and a map. While you will also need to keep an organized filing system for images and data on a computer, the advantage with GIS is that you will be able to search and retrieve images in a much more efficient manner. Moreover, you can integrate the GBPM system with other M&E or GIS data layers.

Other image library and database software are available, if you have the financial resources to purchase them. **Adobe Lightroom** is a powerful software package for GBPM as you can tag keywords and add data directly into the images' metadata. It is also a very efficient platform through which to view, search, and retrieve images. Its weakness is that the software package is relatively expensive (about US$100, as of 2014) and it is unlikely that it would be complementary to other office uses.

Image Database Archival

Since GBPM is a long-term project, backing up your image database is critical. Hard drives crash, viruses spread, and power surges or outages are all risks that can wreak havoc on your computer's memory and file storage. Back-up your image database for future retrieval using one of several methods; the method you choose will depend on the resources and personnel you have available. Of course, your project office may already have a back-up system in place that can be used for GBPM data. However, keep in mind that the accumulation of high-resolution images over time can consume massive amounts of storage memory and plan accordingly.

CD-roms can be good means of archival as they are readily available, relatively inexpensive, and easily stored in your office. Burn copies of your Excel or GIS files, image files, and maps onto CDs as soon as you have finished tagging and consolidating your data. Not all burned CDs are compatible with every computer system, so be cautious as to which systems are in use and be aware that you may need to periodically update or re-burn your data on new CDs.

External hard drives are a good means of archival if you have the means to purchase one. Fortunately, the costs of such devices have decreased greatly in recent years and drives capable of storing a terabyte of data are available for about US$150. External hard drives have a large storage capacity and are quickly and easily accessed for future use from multiple computers. You can also store software files on a hard drive. However, be cautious that you do not infect your hard drive with a virus from your computer or while sharing files from computer to computer. Maintaining an automatic virus protection system is highly recommended.

You can also archive your files on a **web-based platform**. Perhaps your organization has a website on which reports or other documents are stored and shared among staff and perhaps external collaborators and other audiences. If you have somewhat stable access to the internet and are able to upload your files or database online to cloud storage systems such as Dropbox, this is a good option as it circumvents common localized computer risks like viruses and power outages. Such storage can also provide easier access to your GBPM images and survey by a larger group of users working in different locations.

Uploading Data

The process of uploading your data can be broken down into three steps: 1) uploading the images, 2) uploading the GPS points, and 3) transcribing or scanning the datasheets or logbook.

Uploading the photos entails copying the files from your camera onto a computer. It is helpful to organize these photos into different folders based on area and photo-point. For example, if photo-points 1, 2, and 3 were taken in the Tsega micro-watershed and photo-points 4, 5, and 6 were taken in the Weinalem micro-watershed, you could create and name two folders for each one with three folders within each for the photo-points.

If you have time, it can be useful to rename the photos by their coded name according to your established naming system. This may be too time-consuming given your workload. As long as you record the images' filenames on the datasheet and know which files are from which photo-point and position, you can leave the file names as they are.

Uploading the GPS points entails copying the geo-location information from your GPS device to your computer and/or into your image database system (e.g., GIS or Excel). Refer to the GPS manual for specific instructions. Some devices may require dedicated software. Ensure that the points are sufficiently named so you do not confuse the points.

Uploading the data from your datasheet or logbook entails transcribing your notes into your image database system, such as an Excel spreadsheet or GIS attribute table. If possible, it is helpful to scan a copy of the data from each photo-point as back-up or for future reference, in case you lose the datasheets or logbook. You can store scanned files in the photo-point folders that were created to store GBPM images.

If you are using Excel, create a template similar to your datasheet or logbook with all the information recorded. In addition, add a 'Keywords' column to the image table in which you can tag your images with the appropriate keywords from the list you have defined (see below).

Field Data Sheet (sample)

Date and Time: 10 December 2009; 13:15

Photographer: John Doe, M&E Specialist

Photopoint: T00-101201-001

GPS Coordinates: "Point 031001-001"
UTM 37M 0235401 9889859

Field Notes:
Fish farming site, waste material, roadside, evidence of construction

Excel Table (sample)

Photo Name	*Date*	*Time*	*Keywords*
T00-101209-001-001	10.12.2009	13:15	road
T00-101209-001-002	10.12.2009	13:16	aquaculture
T00-101209-001-003	10.12.2009	13:17	building material

If you are using GIS, create columns in your attribute table to record all the data (e.g., photo-point name, location description, image filenames, keywords). We will assume that if you are using GIS, you will have someone on your staff with enough knowledge and experience with the program to create the database and an appropriate attribute table.

Tagging Keywords

The process of tagging keywords will depend on which database system you are using. However, it essentially entails examining each image and identifying which

Figure 15. An image at photo-point #4 in Kijabe, Kenya shows beekeeping (highlighted in pink) and eucalyptus trees (highlighted in blue).

keywords describe observable conditions. For example, Figure 15 is a photo-point showing an ecoagriculture intervention (beekeeping) and a biological feature (eucalypt forest), both of which are keywords.

Enter each keyword that is present in the image into the keyword column (Table 5). Remember, keywords must be visibly discernable from the image. For example, if wild monkeys are on your keyword list and you know monkeys live in the forest that is depicted in your image, it does not mean you can tag the image with the monkey keyword. You have to see the monkey in the image in order to tag it with that keyword. Do not be tempted to tag things that are not visible in the image.

The keyword tagging process may feel tedious and time-consuming. It can be, but the benefits will far exceed the costs. To ease the workload, you can pace this task over a longer period of time, perhaps tagging keywords for one or two images a day. This task can also be share among the GBPM team, but remember, if you decide to share the responsibility be sure that everyone is in agreement about what constitutes the presence of each keyword. It may be helpful to run through a few examples as a group, so that everyone understands the process and the specifics of the keyword list.

Searching the Database

Once you have finished keyword tagging images in the database, you will be able to retrieve all the images with a particular keyword. For example, say you want to see how many photo-points have deep trenches as a land management intervention. In Excel, you can use the Find tool (ctrl-F) and then simply type the words 'deep trench,' press enter, and it will highlight all the rows (i.e., images) where the keyword 'deep trench' was tagged. You can then retrieve those images from your files. You can also search by date, photographer, location, etc. Similar tools exist in GIS and library software.

Step 6 ∘ Comparing Images for Change Over Time

In this section you will:

Learn about the importance of comparing images taken from the same photopoint, at different points in time to help draw conclusions about the success of your program's management interventions.

Learn that while quantitative or quantitative methods of image comparison can be used, methods that engage local stakeholders in a visual comparison are exceptionally useful.

Once you have taken two images from the same photopoint (e.g., T_0 and T_1), or a have a historical repeat photograph (e.g., T_h and T_1), you can begin comparing them for observable changes. There are many methods of analysis, from the simple to the complex. For instance, Hall (2001, 2002, 2005, 2007) used a grid analysis to detect physical shifts in riverbanks and vegetative growth. Michael et al. (2010) used more sophisticated techniques, such as eCognition software to map images and their features based on colors.

While minute changes or precise measurements of change may require grids or additional software, many changes will be obvious in a simple side-by-side comparison. For example, two images from Pennsylvania, clearly show increased forest cover in the surrounding hills over a period of about 90 years (see Figure 16). You can also use tagged keywords as a guide in your analysis, comparing keyword tags to see if a new tag is present or a previous tag is now absent.

It may be useful to call upon other individuals or groups for assistance in image analyses, as different people will notice different changes. Moreover, involving community members in analyses can initiate important discussions about the impacts on the landscape resulting from your land management interventions. Such observations can be recorded in the image database or in other reports or documents.

Figure 16. Two images from Snake Creek Valley in Susquehanna County, Pennsylvania, USA show increased decidious forest cover and vegetative growth in the time between 1920 (left) and 2008 (right) (from L. Myron, unpubl.).

Part 4

GBPM Case Studies

Part 4 of the user's guide on ground based photo-monitoring presents two case studies of GBPM in practice. The first case study illustrates the application of GBPM in the context of an ecoagriculture initiative in the Lari landscape of Kenya, under the auspices of a community organization called KENVO. The second case describes the piloting of a GBPM initiative in the context of a sustainable land and water management project in the Burqa Abagabir Watershed in Southwest Tigray, Ethiopia, in collaboration with the Ministry of Agriculture's Sustainable Land Management Programme.

Case Study

The Lari Landscape in Kenya

Figure 17. The Kikuyu Forest Escarpment, Kenya .

Context

This case study illustrates a practical example of a GBPM survey piloted in a mixed forest-agriculture landscape mosaic in central Kenya. Its implementation was coordinated by a team consisting of leadership from community based organization KENVO (Kijabe Environmental Volunteers), a spatial analysis consultant who holds a position with Kenya's Ministry of Research, Science and Technology, a communications design consultant and two authors of this guide. The pilot survey was conducted over a three day period in July, 2011 to explore the feasibility of using GBPM to monitor KENVO's progress in bringing about an integrated landscape system of agriculture and natural resource management. Highlights from this pilot are presented below with reference to the methodology presented in Part 3.

Background

KENVO, the Kijabe Environmental Volunteers, is a non-profit conservation and rural development organization operating in the Kikuyu Forest Escarpment between the Aberdare Mountains and the Great Rift Valley on the outskirts of Kenya's capitol, Nairobi (see Figure 17). The organization has three primary objectives. The first is to conserve and restore forest ecosystems through activities such as tree enrichment plantings, and limiting access by people and livestock to parts of the forest that are regenerating. The second is to diversify and intensify agricultural systems through practices such as beekeeping, fish farming, stall-feeding of livestock and agroforestry. The third objective is to market eco-certified products and eco-system services that the landscape produces and delivers through a variety of sustainable land management activities and cooperative forms of organization.

The variety of sustainable land and water management (SLWM) practices that will contribute to realizing the project objectives have visual dimensions to them, while implementing and adapting these over the long-term is required to have the desired impact. For these reasons, ground based photo-monitoring (GBPM) was viewed as an effective tool for assessment. In addition, the images produced will serve as an effective communication tool to prompt dialogue among members of KENVO and the local communities in realizing their objectives for the performance of the landscape. Hence, a GBPM survey was designed following the steps outlined in Part 3 of this manual.

Step One

Assembling the GBPM Team

Identification of the GBPM team was the first step in developing the GBPM project for KENVO. The four roles (spatial representative, land management projects representative, photography representative, and database management representative) were assumed by three people. That said, the roles of the project team members were flexible and many responsibilities were shared across the team.

The spatial representative role was assumed by Mwangi Githuru. He was selected for his proficiency in using spatial data materials and equipment, his strong familiarity of the Kijabe landscape, and his knowledge of roads and transportation routes to sites of interest. David Kuria was selected as the project representative for his understanding of KENVO's project activities, of short-term and long-term variations in the landscape, and his knowledge of roads and transportation routes to sites of interest. The photography representative was filled, temporarily, by Lindsay Myron, a student of Cornell University at the time. She was selected for her experience with photography and the GBPM methodology. She was expected to train KENVO staff in basic photography skills to assume this role later. Lindsay Myron also served as the database management representative and was expected to train a KENVO staff in the skills necessary to assume this role in the future. The KENVO GBPM project team was assisted by Dr. Louise Buck from Cornell University and Jared Crawford of Mathews Safari. They helped coordinate the team and focus the GBPM project.

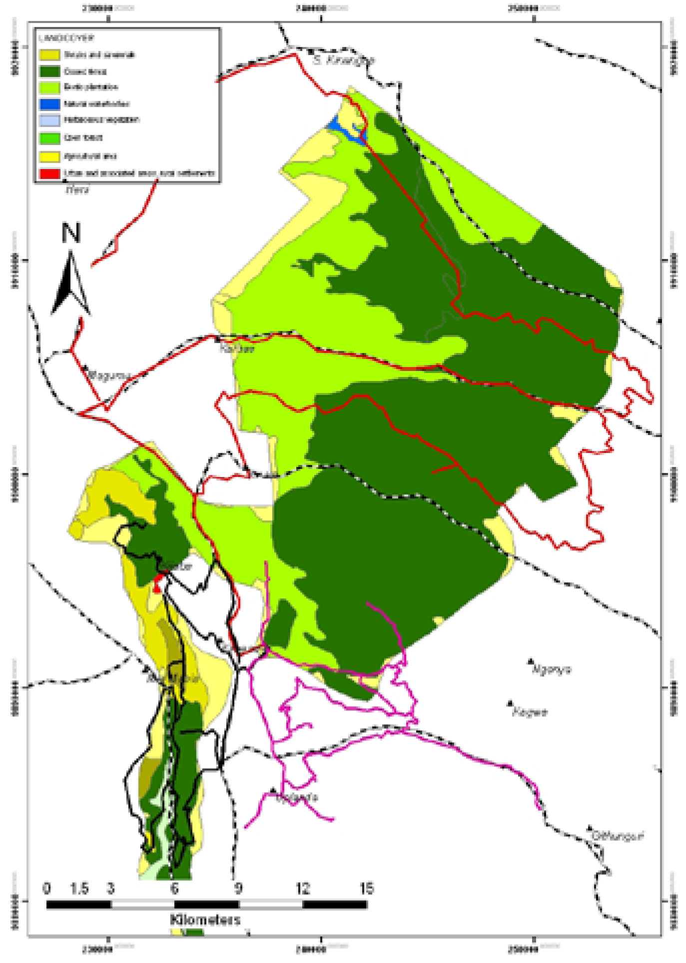


Figure 18. A map of the Lari Landscape in Kenya.

Step Two

Developing the Analytical Framework

The second step in developing KENVO's GBPM system was deciding which features and drivers of change needed to be monitored. KENVO's GBPM team decided that they wanted to assess the implementation of the organization's first two objectives: to conserve and restore forest ecosystems and to diversify and intensify agricultural systems.

Regarding the first objective, the team discussed potential keywords that, if visible, would indicate progress towards this goal. Some of these keywords included: forest and tree plantations, forest regeneration sites, forest and vegetative cover, and agroforestry.

The second objective had been addressed by KENVO through several intervention projects such as beekeeping, fish farming, agroforestry, and forest rehabilitation. The team discussed several established sites within the Kijabe landscape that had these project interventions and described their features. For example, fish farming sites have ponds with shrubbery surrounding their perimeters that provide fodder, windbreaks, and shade; beekeeping sites have hives and are often fenced; and rehabilitation sites have tree saplings and clear borders between developed and developing forest. The project team decided that these features would serve as good keywords, which, when present, would document progress towards their second objective.

Step Three
Designing a Sampling Strategy

The KENVO GBPM team discussed their project objectives and the challenges they might face within the landscape. The terrain was difficult and road access was limited. Moreover, because of previous delays, the team only had two days to conduct their field data collection. The various project interventions the team sought to survey, such as reforestation sites, were interspersed throughout a large area, but some of the features, specifically with regards to the second objective, were site specific.

Following their discussion, the team decided to approach their GBPM survey using two different sampling methods, one for each objective. With regards to the first, the team decided to apply an opportunistic sampling method because many of the forest regeneration sites were situated on rugged terrain and would have been too difficult to access given the short amount of time available. Regarding the second objective, the team decided to apply a strategic sampling method because of the site-specific nature of the project interventions and their ease of access along their proposed sampling route. The team used the map of the Lari Landscape and environs depicted in Figure 18 for planning their sampling strategy.

Figure 19. A fish farming intervention site in Kijabe landscape, Kenya. Image T00-052110-003-02-001 taken May 21, 2010.

Step Four
Field Implementation

The members of the KENVO GBPM team and Louise Buck conducted their field survey on May 20, 2010 for assessing the first objective and on the following day for assessing the second. In this example, we will briefly mention three photo-points established on the second field day.

The first photo-point was established at a fish farming pond. The site was owned and managed by a local resident. The GBPM team spoke with the property owner to learn more about the current status of the pond and determined that this particular site was in relatively good condition. The pond was productive and the shrubbery surrounding the pond was lush, had supplied fodder, and was providing a good shield from wind and direct sunlight.

The photography representative set up a photo-point (T00-052110-003) in the corner of the yard, from which point the pond and shrubs were visible (see Figure 19). The following data were then recorded:

Photopoint:	T00-052110-003
Date and Time:	21 May 2010; 13:21
GPS Coordinates:	"K-052110-003" UTM 37M 0235401 9889859
Field Notes:	Fish farming site

Images (Nikon D200, JPEG)

T00-052110-003-02-001	T00-052110-003-02-003	T00-052110-003-02-005
T00-052110-003-02-002	T00-052110-003-02-004	T00-052110-003-02-006

Figure 20. A beekeeping intervention sites in the Kijabe landscape, Kenya. Image T00-052110-004-02-003 taken on May 21, 2010.

The next photo-point was established at a beekeeping intervention site located within a tall eucalyptus stand owned by an absentee landowner. The GBPM project representative explained that this particular beekeeping site was located in a wet, marshy area not ideal for its intended purpose. Identifying this site as inadequate and recognizing physical characters that indicated its lack of success (i.e., wet marsh) introduced a new visual indicator to be added to the keyword list.

The photography representative set up the photo-point (T00-052110-004) where the beekeeping site, marsh area, and eucalypt stand were all visible. An example image is shown in Figure 20. The following information was recorded:

Photopoint: T00-052110-004

Date and Time: 21 May 2010; 13:48

GPS Coordinates: "K-052110-004"
UTM 37M 0235112 9887404

Field Notes: Beekeeping, poor conditions, wet, marshy area poses challenge.

Images (Nikon D200, JPEG)

T00-052110-004-02-001	T00-052110-004-02-003	T00-052110-004-02-005
T00-052110-004-02-002	T00-052110-004-02-004	T00-052110-004-02-006

The third photo-point established was a forest rehabilitation site. The project representative explained that forest rehabilitation sites are intended to reforest areas of past exploitation. As such, natural borders (e.g., boundaries between forests and open fields) are prominent physical characters that lessen over time indicating a positive change. Moreover, the quantity and quality of indigenous tree species also indicated positive change.

The photography representative set up the photo-point (T00-052110-007) along the border of this site. An example image is show in Figure 21. The following information was recorded:

Photopoint: T00-052110-007

Date and Time: 21 May 2010; 15:07

GPS Coordinates: "K-052110-007"
UTM 37M 0239479 9891603

Field Notes: Rehabilitation Forest, natural borders diminishing

Images (Nikon D200, JPEG)

T00-052110-007-02-001	T00-052110-007-02-003	T00-052110-007-02-005
T00-052110-007-02-002	T00-052110-007-02-004	T00-052110-007-02-006

Step 5

Organizing, Storing and Analyzing Data

Since the KENVO team was also testing the use of three different camera types (DSLR, point & shoot, and cell phone) in this pilot survey, they added another element to the naming system (i.e., camera used).

Uploading Data and Organization

KENVO's GBPM project was organized in a series of folders for each photo-point with subsequent folders for each camera type (e.g., Nikon DSLR, Canon Powershot, Android cell phone). A text document with the field data was saved in the main folder of each photo-point. Image files were renamed based on the naming system (see Figures 22 &23). In addition, a document explaining the organizational system was saved within the GBPM project folder so that anyone at KENVO would be able to quickly navigate the database and access the files.

Keyword Tagging

Keyword tagging and analysis were tasks mostly left to the KENVO staff on the GBPM team; however, we will provide a brief example from the forest rehabilitation site (see Figure 24).

Keywords identified in the analytical framework that were identified in this image included tree plantings, tree saplings, and open field. On a large scale, the open field indicates that this forest rehabilitation area was still at a beginning stage and the objectives have not been yet been met or not yet attempted. Identifying the open field in this image offers KENVO a simple assessment of the current status of the area. On a small scale, the tree plantings indicate that forest rehabilitation is being attempted. The presence of tree saplings is a simple, clear indication that KENVO's objectives are being addressed. Comparing this image with images

Figure 21. A forest rehabilitation site. Image T00-052110-007-02-006 taken on May 21, 2010.

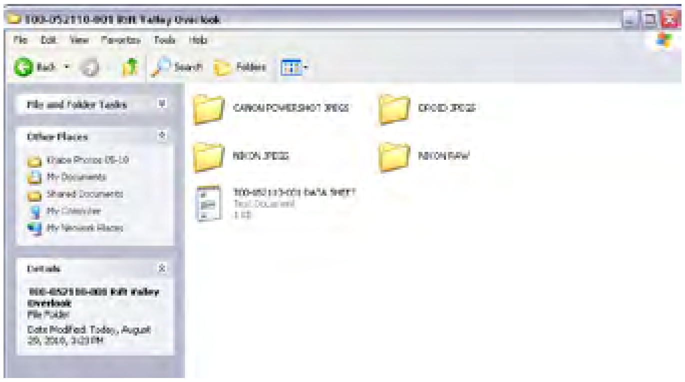


Figure 22. A screenshot of the organized folder for photo-point 001.

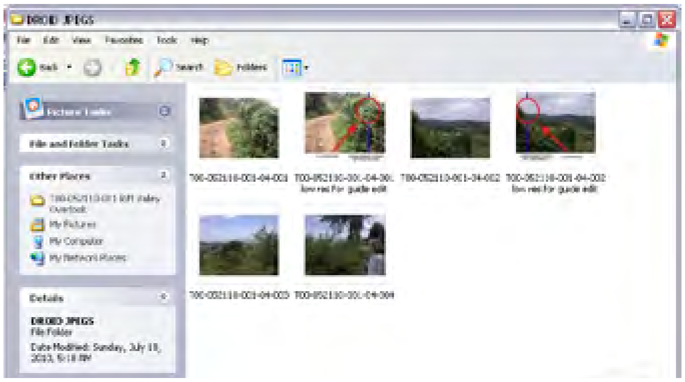


Figure 23. A screenshot of the cell phone camera image files, renamed according to the naming system.

Example	Code	Description
Too	Time X	Indicates the photo-point repeat number, where Too is time zero, To1 is repeat one, and so on.
052110	Date	Shorthand for the month, day, and year when the photo was taken (MMDDYY).
006	Photo-point	Indicates the photo-point number within the survey where 006 is photo-point #6.
03	Camera Type	Indicates the camera type used to take the camera, where 01 was the DSLR, 02 was the point & shoot, and 03 was the cell phone camera.
002	Image Number	Indicates the photo number taken at the photo-point.

Table 4. A breakdown of the naming system used in KENVO's GBPM project.

taken in the future, KENVO may see that the open field is diminishing in size and that the saplings have grown in size or number, which would indicate that their project intervention is proving successful.

Figure 24. A forest rehabilitation site. The area highlighted in purple shows an open field with tree plantings shaded in blue.

Case Study

The Burqa Abagabir Watershed In Southwest Tigray, Ethiopia

Figure 25. The Burqua Abagabir Watershed, Ethiopia

Context

This case study illustrates a practical example of a GBPM survey piloted in a large watershed in Ethiopia (see Figure 25). Its implementation was coordinated by a team consisting of GBPM consultants and sustainable land management (SLM) practitioners under the support and cooperation of EcoAgriculture Partners, GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit), and the Ethiopian Bureau of Land Management and Bureau of Agriculture. The pilot survey was implemented over the course of a five-day field trip to the Southwest Tigray Region of Northern Ethiopia during the second week of January 2014. Details of this pilot are presented below with reference to the methodology provided in Part 3.

Background

The Burqa Abagabir Watershed in the Raya Azebo District of South Tigray is an area seriously affected by land degradation. The causes of land degradation are complex and diverse. In addition to the effects of climate and topography, land degradation in the highlands of South Tigray is the result of increasing population pressure that subjects the land to exploitive natural resource use and rudimentary agricultural production methods. Overgrazing, poor farmland management, deforestation, the over-harvesting of wood and other biomass for fuel and construction, and intense and erratic rainfall accelerate this land degradation on a watershed scale. The highlands of Tigray are especially affected by sheet and gully erosion. As a result, the soil is highly eroded and there are marked moisture, fertility, and biomass declines in addition to social effects felt by local communities, such as food and income insecurity.

To address these problems in the Raya Azebo District, Sustainable Land and Watershed Management (SLWM) projects have been initiated through the coordinated efforts of different stakeholders, including the local government, development NGOs, sponsoring agencies, research institutes, and farming communities, each with different responsibilities and objectives. One such SLWM effort has been undertaken for the past five years in the lower Burqa Abagabir Watershed with major support from the World Bank. Projects undertaken in this area include soil and water conservation practices, land rehabilitation strategies, reforestation and biodiversity initiatives, and livelihood diversification. Thus far, existing monitoring and evaluation (M&E) investigations have shown positive results with communities noticing positive differences in both their livelihoods (e.g., improved income and agricultural productivity) and the environment (e.g., reduced soil erosion and drought).

Nonetheless, stakeholders agree that conducting effective M&E of SLWM initiatives – both achievements and challenges – is crucial for informed development and up-scaling to other regions. While existing M&E strategies are both formal and informal in nature, they are challenged by the capacity of the personnel conducting them; these challenges include limited time that can be devoted to M&E and limited understanding of the metrics used for completing each report. Moreover, M&E results must be communicated to a variety of groups with varying levels of education and experience. Hence, an integrated approach to M&E that is inclusive of different methods and tools is important.

The application of GBPM was deemed viable and useful for this context because of its capacity to strengthen existing M&E efforts and easily communicate long-term SLWM impacts to all stakeholders, from benefactors at the World Bank to local community members. A pilot test of GBPM as a tool to monitor landscape changes resulting from SLWM initiatives was approved for implementation in the lower Burqa Abagabir Watershed of Southern Tigray in collaboration with the Sustainable Land Management Program (SLMP) of Ethiopia. The pilot established a replicable procedure for using GBPM as a tool for engaging land users and other stakeholders in M&E of changes in land use and land cover at the watershed scale.

Step 1

Assembling the GBPM Team

The first step in developing this GBPM survey was to assemble a GBPM team. For this pilot, individuals were not selected to fill each of the four roles (i.e., spatial, SLM projects, photography, and database management representatives). Instead, a core group of five people cooperatively fulfilled the roles in order to learn and understand all of the responsibilities. These individuals included: the M&E Advisor from the GIZ Tigray office, two SLM Advisors from the Mehoni village office in South Tigray, and two external GBPM consultants from EcoAgriculture Partners. We will refer to this group as the Tigray Team.

The Tigray Team spent an hour reviewing the Step 1 material from Part 3 and discussed the traits and responsibilities of each representative. The team identified strengths of each team member and how they might best contribute. For example, the two SLM Advisors knew the SLM projects the best, characteristic of the SLM projects representative, while the M&E Advisor was capable of storing and organizing large amounts of data, characteristic of the database management representative. During this time, the Tigray Team also discussed how to integrate community involvement into the project, noting that community members knew the landscape's area, accessibility, and seasonality very well, and could therefore serve as spatial representatives. The Tigray Team recruited the involvement from three members of the Community and Kibele Watershed Teams, leadership groups that manage the SLM projects at the local level.

Review from Part 3

There are four primary roles in a GBPM team, which we call representatives:

- spatial representative
- SLM projects representative
- photography representative
- database management representative

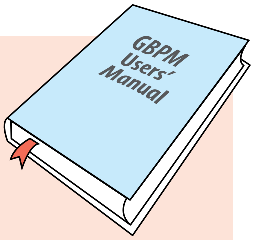
These roles can be filled by one person or a group of people and can be mixed or separated further depending on the personnel you have available.

Each representative contributes specific knowledge and skills.

Step 2

Designing the Analytical Framework

The second step in developing the GBPM survey was to design the analytical framework. To begin, two members of the Tigray Team conducted interviews with various people involved in SLWM management and oversight. The following people were consulted: the M&E Advisor at the National GIZ office, the Deputy Director at the GIZ Tigray office, the M&E advisor at the GIZ Tigray office, members of the Woreda Watershed Team (the local SLM advisors in the Raya Azebo District), and members of the Community and Kibele Watershed Teams (local SLM leadership groups). Questions discussed during these interviews addressed the threats to the Burqa Abagabir landscape (e.g., gully erosion, deforestation for fuelwood), the objectives of SLWM interventions in the area (e.g., improve soil fertility,



Review from Part 3

The **analytical framework** provides the context and structure necessary for interpreting visual changes in the landscape that are detected in GBPM images.

The basic goal of an analytical framework is to design a set of **keywords** which stem from project-based indicators of change and can be visually observed over time (e.g. T_0 vs T_1).

Keywords must be visually identifiable from a photograph on a presence or absence basis; qualitative or quantitative terms (e.g. increased, improved) should be saved for analyses, when possible.

We present a suggested workflow for identifying keywords in Part 3, Step 2, which recommends considering the visual aspects of the following:

- The baseline status of the landscape
- Threats to the landscape
- SLM project interventions
- Resulting short- and long-term changes to the landscape

Potential sources of keywords could come from discussing the aspects listed above with your GBPM team, SLM or M&E advisors, and/or local community members in addition to referencing SLM project documents and/or M&E reports.

reforestation), the potential and/or actual results of those interventions (e.g., species composition, agricultural productivity), and the strengths and weaknesses of current M&E efforts. Responses to these questions and common terminology used that could be included as keywords were compiled into a list following the interviews.

The Tigray Team then met for approximately two hours to design their analytical framework. The Tigray team first reviewed the material presented in Part 3 and worked through the suggested workflow by describing each aspect one at a time. For instance, regarding the baseline status of the landscape members of the team individually described the visible features of the Burqa Abagabir Watershed, such as its steep hillsides, perennial and seasonal rivers, indigenous species (e.g., the *Shilen* tree), and cultivated crops like sorghum, sweet potato, and elephant grass. The team similarly discussed current threats to the landscape and causes of land degradation, current SLM interventions and projects, and projected outcomes, both short- and long-term.

One team member served as the scribe and took notes throughout the discussion, keeping a list of all potential keywords mentioned. Additionally, responses from the interviews conducted in the days prior were integrated into the discussion in order to highlight repeated terms and include terms otherwise not mentioned.

The Tigray Team then modified the list to include only visibly discernible features that could be identified on a presence or absence basis. For example, "increased wildlife" was a potential long-term change to the landscape that was mentioned during the discussion. While you may notice an increase in wildlife when comparing two repeat images side-by-side, it would be impossible to identify the presence of *increased* wildlife in a single photograph. As such, the team modified this keyword to strictly "wildlife" and added some more specific keywords such as "monkeys," because the presence of both can be visually observed in a single image.

At the end of their discussion the Tigray Team produced a list of keywords (see Table 5) that could be logically divided into three basic categories (baseline landscape features, threats to the landscape, and SLM interventions) and several sub-categories. The keywords and their variations (e.g., cropland, irrigated cropland, perennial cropland), are listed in the third column of Table 9. The categorization served as a means of organizing the list of keywords into a more logical order and was not essential to the analytical framework; you may also notice some keywords are repeated under separate categories.

Although this keywords list that the Tigray team developed during their discussion was not exhaustive, it was an effective exercise of the method for developing an analytical framework and it established the basic structure through which the team would be able to interpret changes detected in their GBPM images.

Step 3

Designing a Sampling Scheme

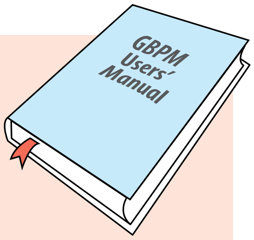
The third step involved designing a sampling scheme for the GBPM survey. The Tigray Team met and reviewed appropriate material presented in Part 3. They then discussed spatial considerations, including the distribution of features of interest that they wanted to capture (e.g., SLM diversion channels, planted gullies) and potential limitations of surveying the landscape (e.g., road access, terrain) and personnel (e.g., time available, transportation).

The Tigray Team discussed the four types of sampling strategies presented in Part 3 (i.e., random, opportunistic,

Category	Sub-Category	Keywords (variations)
Baseline Landscape Features	Land Classification	Cropland (rainfed, irrigated, perennial, annual)
		Grazing land (extensive, intensive, pasture)
		Forest (natural, plantation)
		Mixed (livestock and crop farming, agroforestry)
		Other (tree nursery, beekeeping, mines, settlements, roads, trails, waterways)
	Watershed Zones	Upstream, downstream
	Water Resources	Permanent surface water, seasonal surface water, fluctuating surface water, springs, perennial rivers, seasonal streams, ponds, groundwater, Gugur River
	Species Composition	Trees, shrubs and other (cacti, shilen, wanza, woira, momona)
		Cultivated grains (teff, sorghum, triticale, wheat)
		Fruits and vegetables (papaya, mango, apple, cabbage, tomato, sweet potato)
		Animals (cattle, sheep, goats, equine, chickens)
		Grazing fodder (saltbush, elephant grass)
	Structural Features	Gullies, rills, ditches, dams, mountain chains, hillsides, river banks, valleys, sediment depositions
Threats to the Landscape	Degree of Degradation	Severe, moderate, low, none
	Erosion	Water erosion, sheet erosion, gully erosion, rill erosion, riverbank erosion, landslides, sedimentation
	Physical Deterioration	Compaction, sealing, crusting, waterlogging
	Biological Deterioration	Pests and diseases, chochineal insect, wild animal predators
	Chemical Deterioration	Pollution, salinization
	Human-Induced	Farmland fragmentation, free-grazing of livestock, overgrazing, cutting of wood, expansion of cropland, discharge or pollution, charcoal production, monocropping, low-yielding breeds/species
SLM Interventions	Livestock	Improved forage varieties, forage abundance around fields, cut-and-carry, hay production, fattening
	Crop Production	Improved crop varieties, intercropping, vegetable production, fruit production
	Forestry	Plantations, agroforestry, improved tree species, indigenous trees, vegetation cover, tree nursery
	Water and Soil Conservation	Water-harvesting, irrigation, planted gullies, soil cover, deep trenches, normal trenches, percolation ponds, terraces, planted bunds, stone bunds, soil bunds, check dams, diversion channels
	Livelihood Improvement / Diversification	Beekeeping, fruit trees, winter harvest, gully planting, fattening
	Management	Area enclosures for rehabilitation
	Biological	Wild animals, indigenous trees

Table 5. List of keywords developed by the Tigray Team for GBPM in the southern Burqa Abagabir Watershed.

strategic, quota) and the strengths and weaknesses of each. While the team saw the objectivity that would result from more statistically powerful approaches (i.e., random, opportunistic) as valuable, they decided that a less demanding approach would suit the team and the area best as their personnel was limited in both time and access. That is, the Tigray Team confirmed that random sampling would yield photo-points in locations that could be too difficult to access while opportunistic sampling would require too much time to complete. Moreover, the team already knew



Review from Part 3

A GBPM sampling scheme determines where you will establish photo-points and how often you will sample them.

Devising a unique sampling scheme for your specific landscape will help you effectively capture specific landscape features or changes you want to monitor while maintaining a desired level of objectivity and pragmatism.

Devising a sampling scheme involves spatial, temporal, and frequency considerations, which are tempered by limitations in access, time, money, and personnel.

Four suggested sampling schemes that address spatial considerations are: random, opportunistic, strategic, and quota (see glossary for full definitions).

Temporal considerations include time of day and time of year to sample, variations of which affect light quality, quantity, and visibility

Frequency considerations include the intervals at which you will resample your photo-points (e.g. every month, every 10 years) and depends on what you are seeking to monitor.

the key features that they wanted to capture (i.e., SLM interventions) and where those features were located. Therefore, they confirmed that a sampling scheme that was flexible enough to permit in-field photo-point establishment at ideal locations was best. While they saw both quota and strategic sampling methods as applicable, in the end they selected strategic sampling as their method because their SLM Advisors would be able to sample photo-points as many times as they were able during regular visits to the watershed, which does not have pre-determined routes.

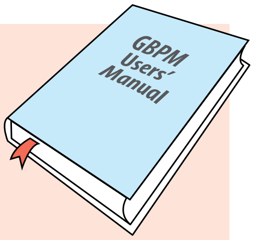
During their discussion, two of the SLM practitioners on the team mentioned how current M&E efforts were time-consuming and challenging to complete by set deadlines, often because other tasks and responsibilities often took precedence. As such, they thought a sampling scheme with strict sampling times and intervals would be unrealistic and very difficult to implement. The team still discussed the limitations that might be posed by seasonal variations in the landscape, plant life cycles of interest (e.g., crops), and air quality and visibility, but ultimately decided that although annual repeat photographs would be attempted, photo-points would be sampled whenever the team was able. Because of this decision, the team was reminded by the GBPM consultants that special attention to the date and time of the samples will be absolutely necessary when making comparisons between repeat images.

Because time was limited for the implementation of this pilot survey (i.e. five days in the field), the team pre-selected two micro-watersheds to sample within the lower Burqa Abagabir that were close to their office in Mehoni village: the Tsega and Weinalem. In addition, the SLM Advisors on the Tigray Team knew of some SLM interventions of interest that were easily accessible.

Step 4
Field Implementation

Field implementation was the fourth step in establishing this GBPM survey. Prior to departing for the field, the Tigray Team created a naming system and datasheet format to be used in during the survey. The naming system for their photos had four parts that indicated the repeat frequency, date, photo-point number, and image number.

The Tigray Team used a data logbook in the field with a standardized format that included the following fields: photo-point name, date and time, photographer, photo-



Review from Part 3

Basic field equipment includes: digital camera, memory card, GPS, map of landscape, datasheets or logbook, pencil, prints of previous photographs (if re-sampling). Other equipment can include a tripod, bubble level, or compass.

Creating a naming system and datasheet or logbook format prior to fieldwork is important for keeping data organized.

Establishing a new photo-point entails recording basic data in the logbook such as the GPS coordinates, weather, and a description of the photo-point location; stabilizing the camera and capturing images; and recording image filenames and azimuth (if using a compass).

Re-sampling a photo-point entails navigating to the photo-point using GPS, map, and/or photo-point location description; positioning the camera in the same location and direction as previous photos; capturing the images; and recording the data in the logbook.

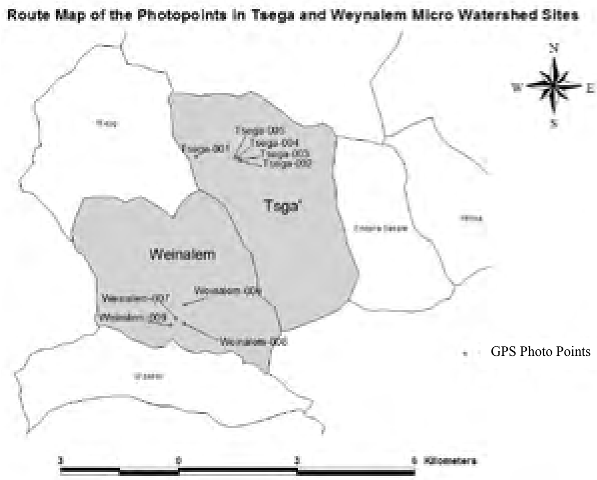
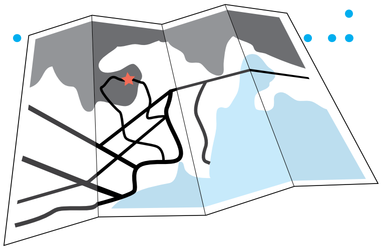
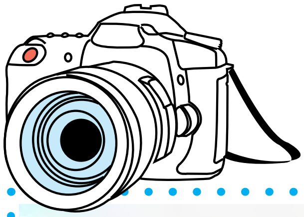


Figure 26. Map depicting sampled photo-points established in Tigray, Ethiopia. (see Figure 10, pg. 22 for full size figure).

Figure 27. Members of the Tigray Team capture GPS and compass data while the scribe (at left) records the data in the logbook for a photo-point in the Tsega micro-watershed.





point location description, GPS coordinates, weather conditions, and field notes. A table with the image names, image filenames, and compass directions was included at the end of each page.

The team gathered their equipment which included: a point-and-shoot camera, a DSLR camera, a GPS device, a map of the landscape, a compass, a data logbook, pencils, and two prints of historical images to be re-photographed. Upon reaching the Tsega micro-watershed, the Tigray Team recruited the assistance of three Community Watershed Team members who helped locate and select ideal photo-points. A total of nine photo-points were established during the single field day (January 11, 2014), two of which were repeats of historical photographs. Of course, many additional photo-points were possible but the team had only one day to initiate the field survey and illustrate the sampling process.

The first two photo-points to be established had photographs that were taken about two years ago by one of the SLM Advisors on the team. He knew the general area where these photographs were taken and the team spent some time aligning the background and foreground features to replicate the image. For example, the first historical photograph to be re-sampled had a visibly recognizable convergence of hillsides in the background and some distinguishing features in the middle-ground and foreground, such as a gully and some SLM interventions.

To repeat the image, the Tigray Team stood on the hilltop where the SLM Advisor said he had taken the original image. The team held the printed copy of the former photograph up to eye-level and positioned themselves in a location where the hillside convergence angle in the background was identical. Because the photograph was taken only two years ago, the team was able to use small-scale biophysical features, such as a distinguishing cactus, in the foreground to position themselves correctly. They also used the angles

Figure 28. The repeat image (on the right) of the Tigray team's first historical photograph (left) captured at the first photopoint, Tsega-001.

of some deep trenches in the middle ground. When their position matched the original photograph, the team steadied the camera and captured the image.

One team member served as the scribe and recorded the following information in the data logbook:

Photo-point Name: Tsega-001

Date: 11 January 2014

Photographer: Lindsay Myron

Location Description: Kase, looking east, above gully

GPS Coordinates: "T01-001"
S 120 26' 14.5" E 320 21' 32.8"

Weather: Hot and dry, hazy, no clouds, bright sun

Field Notes: Mountain in middle-ground ~70% slope, deep trenches

Photo Name (coded)	*Photo Filename*	*Compass Direction*
T01-140111-001-001	BON_0048.JPG	130°

The Tigray Team moved on to establish new photo-points within the landscape of SLM interventions that they wished to capture. The fourth photo-point was established overlooking a valley that had planted terraces in the foreground. The team positioned themselves in a location that had a good view of the valley and the terraces in addition to having some distinguishing features that could be used in the future for relocation. The team's scribe recorded the basic information in the logbook, such as photo-point name, date and time, photographer's name, location description, GPS coordinates, weather conditions, and field notes.

The team decided to capture panoramas at all the new photo-points in order to capture as much of the landscape as possible. One member of the team served as the photographer and positioned the camera to the left of the valley. The photographer steadied the camera, captured the image, and the scribe recorded the filename and compass direction for that image. The photographer then successfully practiced the overlap technique, by aligning a small shrub and a recognizable mountaintop from the right side of the first frame in the left side of the second frame (see Figure 29).

The photographer and scribe captured images and recorded data for each of the photographs in the panorama. Complete data recorded for the photo-point is presented below:

Photo-point Name: Tsega-001

Date: 11 January 2014

Photographer: Lindsay Myron

Location Description: Looking at gully plantation and check dams. On North side of gully. Shilen shrub is behind us at 6m

GPS Coordinates: "T00-005"
S 120 50' 37.7" E 390 36' 51.1"

Weather: Cumulus clouds, slightly hazy

Field Notes: Ragged terrain. Check dams. Treated pasture on other side of gully. Species: geisho, bee flora, safflower, aloe, cactus, shilen

Photo Name (coded)	*Photo Filename*	*Compass Direction*
T00-140111-005-001	BON_0084.JPG	262°
T00-140111-005-002	BON_0085.JPG	212°
T00-140111-005-003	BON_0087.JPG	168°
T00-140111-005-004	BON_0089.JPG	90°

Figure 29. Images 001 and 002 captured at photo-point Tsega-005. The red arrows highlight a hilltop and some crops used to overlap the two photographs.

Step 5

Organizing, Analyzing and Storing Data

The next step in establishing the GBPM pilot survey for the lower Burqa Abagabir Watershed involved data organization, storage, and analysis. Because of limited time, the Tigray Team did not complete this step, but they were able to perform brief exercises in order to learn the process. Team members who remained in the area agreed to finish the work later.

Following the field day, the Tigray Team met to discuss Step 5. The team reviewed appropriate material in Part 3 and then discussed the skill-sets and resources they had available for building an image database. Although the SLM Advisors on the team had sufficient training in GIS and wanted to use GIS to create an image database, their office lacked the needed software. Hence, the team decided to create their image database using Excel, familiar software that was readily available in their office.

To create the image database, the Tigray Team opened a new spreadsheet and created a basic template that was similar to their data logbook format. The team then transcribed field notes, systematically copying photo-points into the spreadsheet

The team uploaded their images and began organizing them into folders. Folders for each photo-point were created and their respective images were saved inside. In the interest of time, the team did not rename the images based on the naming system described in Part 3. Instead, they used the image filenames in the Excel spreadsheet. They may or may not rename the images in the future.

The team then used photo-point Tsega-001 as an exercise for keyword tagging. They first added a column to their Excel spreadsheet next to compass direction and titled it Keywords. The team opened the image file corresponding to Tsega-001 on the computer and examined it as a group. They systematically searched the keywords list and identified those that were visible in the image. If a keyword was present, they added it to the spreadsheet in the Keywords column, next to the image filename. As a precautionary measure, specific species of interest at each photo-point were recorded as field notes in the data logbook in case they could not be easily identified in the image. The final list of keywords for photo-point Tsega-001 can be seen in Table 6.

Photo Name	*Photo filename*	*Compass Direction*	*Keywords*
T01-140111-001-001	BON_0048.JPG	130°	gully, cactus, shilen, mountain, seasonal river, grazing land, bush land, medium, sheet erosion, rill erosion, gully erosion, wood cutting, unusual grazing, chochineal insect, vegetative (tree and shrub cover), structural (deep trenches), structural (percolation channel and pond), sunflower, safflower, reshaping of gullies for cropping, plantations, area closure for rehabilitation, indigenous bush, wild animals, monkey

Table 6. Final list of keywords for photo-point Tsega-001

The Tigray Team then discussed the different ways in which to back-up or archive their image database. Although the team would have preferred using an external hard drive they lacked the financial resources to purchase one and therefore decided that CD-roms would be the best option. They noted that this might be a development for the future.

Step 6

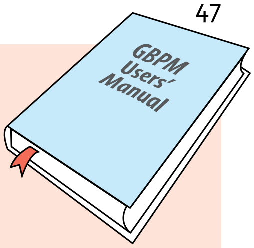
Comparing Images for Change Over Time

Using GBPM as a monitoring and evaluation tool requires comparing images that are collected, organized, and stored as the 'baseline' (time = 0 or T0) with images that are taken later (T1, T2, etc.). This analysis is critical, as such comparisons yield qualitative assessments of landscape changes and the success or failure of management innovations over time.

The Tigray Team discussed image comparison analyses by using photo-point Tsega-001 (one of their historical photograph photo-points) as an exercise. The team opened the image file taken in the field at photo-point Tsega-001 (T01-140108-001-01) on a computer and compared it to the printed version of the historical photo (the same printed copy that they used in the field).

Looking back and forth between the two images the team noticed some growth in vegetation—mostly shilen shrubs and cacti—but otherwise there was little visible changes in the landscape. The team recognized that since the recent image was only taken approximately two years after the historical photo that it would have been unlikely to see any other large-scale changes.

Because the team had limited time they were only able to practice the image comparison process once. However, the team thought that the exercise was suitable and that it gave them enough experience for future image comparison analyses. They reviewed challenges: it's very difficult to identify the specific cause of a change from an image, it's important to keep in mind timing and seasonal changes that may affect conditions, and it's difficult to make quantitative statements about changes in an image, such as "a percent increase in wildlife." However, when following the steps in Part 3 of this manual, they could expect that their image comparisons would provide the basis for rich and informed discussion among land use practitioners and other stakeholders in the SLWM program about the location, the extent and the directions of change in the landscape.



Review from Part 3

Image databases can be created using multiple software/ hardware platforms, such as GIS or Excel. The platform you choose depends on the training and skill-sets you have on your team and the technology and resources you have available.

Image databases should be structured in such a way as to logically organize and store all of the field data you collected, both images and data from the logbook.

You can also incorporate other M&E data into your image database.

Image databases will need to be periodically backed-up to prevent data loss from computer viruses, hard drive crashes, or power surges. You can back-up data on CD-roms, external hard-drives, or cloud-based systems depending on the resources you have available.

It is best to upload your data as soon as you return from the field so as to not lose any information.

Uploading data involves: copying the image files from your camera to your computer, uploading your GPS waypoints from your GPS device to your computer, and transcribing or scanning your data logbook records.

Tagging your GBPM images with keywords is the first step of your analysis. This can be done over a longer period of time and by multiple people if necessary. Tagging images involves examining each image, identifying each keyword present, and recording those keywords in your image database.

Keyword tags enable you to quickly search your database for specific features and/or retrieve images quickly and easily from your database.

Image comparison analysis can occur once you have at least two photos from the same photo-point. It involves identifying changes to your landscape within the two photographs. You can use your keyword list to help you.

Recruit other members of your GBPM team or community members to identify more changes and gain wider insight regarding the changes and their impacts.

Part 5

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Appendix A: Annotated Bibliography

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Notes: From the U.S. Global Change Research Program under the USGS where projects are focused on "Impacts of Climate Change and Land Use in the Southwestern United States". This reference provides an introduction and review of repeat photography as a way of monitoring landscape change. The article specifically looks at ground based and aerial photography. It also includes a good bibliography.

Allen, Craig D., Julio L. Betancourt, and Thomas W. Swetnam. Landscape Changes in the Southwestern United States: Techniques, Long-term Data Sets, and Trends. USGS, 2002. http://biology.usgs.gov/luhna/chap9.html

Notes: Explores the use of historical data to determine the relationship between cultural and natural causes of environmental change in the Southwestern U.S. The article looks at the combination of historical data from the paleobotanical record, repeat photography, and fire scar histories from tree rings.

Bass, Joby. More Trees in the Tropics: repeat photography and landscape change in Honduras. Abstract. Association of American Geographers. Land Cover Change in Western Honduras: Papers in Honor of William V.Davidson, 2003.

Notes: Abstract of a paper presented at a meeting sponsored by the Association of American Geographers. The author describes a repeat photography study conducted in Honduras which showed a net increase in vegetation since 1957. The author notes that understanding ecological change is complex and requires ethnographic as well as ecological data.

Bender, John Richard Jr. 1999. Identifying Structural Differences in Mixed Mesophytic and Northern Hardwood Forests on the Monongahela National Forest Using Remote Sensing Data. West Virginia University.

Notes: A thesis that evaluates whether remote sensing data can replace other methodologies such as aerial photography or field data collection as a more cost effective and efficient way to look at structural diversity, texture and spatial differences between forests. The thesis focuses on the Central Appalachian region. Satellite imagery used in this study includes Landsat Multispectral Scanner (MSS) (80m pixels), Thematic Mapper TM) (30m pixels), and SPOT High Resolution Visible (HRV) Panchromatic data (10 mpixels).

Bueno, Monica, Jon Keeley, and Nathan Stephenson. Repeat Photography Project - Sequoia Kings Canyon National Parks. 1999. 1999 Annual Fire Report on Research, Monitoring and Inventory. Sequoia-Kings Canyon National Parks:USGS, Western Ecological Research Center.

Notes: A summary of a proposed historical repeat photography project in Sequoia Kings Canyon National Park. Aims to show vegetation changes similar to what has been found in Yosemite Valley in other repeat photography projects. At the time this was written they had only found the historical photographs—the field season had not occurred. It might be worthwhile to see if any further papers have been written to update the progress of this project.

Bureau of Land Management. 2004. Observing Change Through Historic Photographs. Bureau of Land Management, Utah State Office.

Notes: This article gives a general overview of historical repeat photography with reference to other studies. It describes how to do a repeat photography study including finding sources for historical photographs, relocating

photo-points, and making comparisons and analysis. Also discusses the limitations of repeat photography.

Byers, Alton C. World Ecotourism Summit Portfolio of Statements and Presentations. 2000.

Notes: A summary of a paper from the Geographical Review. The paper is focused on the alpine areas (above 4,000 m) in Sagarmatha (Mt. Everest) National Park, Khumbu, Nepal where tourism, grazing, fuelwood collection have all impacted the alpine areas. The study uses repeat photography to measure soil erosion, forest cover changes, changes in cultural landscapes; also focuses on alpine areas.

Byers, Alton C. Contemporary Landscape Change in the Huascaran National Park and Buffer Zone, Cordillera Blanca, Peru. Mountain Research and Development 20 (1):52-63, 2000.

Notes: 60 year repeat photography study shows changes in vegetation cover, glacial recession, grazing impacts, and urban expansion in Peru. Included 10 photo-points from historical photographs taken in the 1930s. The article discusses how the analysis from the repeat photos can be used to affect management decisions that are related to land-use changes. Five of the 10 photo-pairs are presented and compared in detail in the article.

Danielsen, Finn, Danilo S. Balete, Michael K. Poulsen, Martin Enghoff, Christi M. Nozawa, and Arne E. Jensen. A simple system for monitoring biodiversity in protected areas of a developing country. Biodiversity and Conservation 9:1671-1705, 2000.

Notes: Offers guidelines on how to monitor biodiversity in a developing country specifically focusing on the Philippines. The goal of the article is to offer a system for monitoring biodiversity that is simple, relatively cheap, and includes local people's participation. It suggests four field methods: 1) standardized recordings of routine observations, 2) fixed point photographing, 3) line transect survey, 4) focus group discussion.

Fensham, R. J. and R. J. Fairfax. Aerial photography for assessing vegetation change: a review of applications and the relevance of findings for Australian vegetation history. Australian Journal of Botany 50:415-429, 2002.

Notes: Reviews studies using aerial photography to monitor vegetation change. Compares using aerial photography with using satellite imagery to monitor vegetation change and concludes that aerial photography has advantages over satellite-based imagery. Makes recommendations on how to improve using aerial photography to monitor vegetation change. Reviews aerial photography studies that monitored deforestation, reforestation, changes in vegetation boundaries, tree density, community composition, and crown dieback.

Franklin, J. F., K. Cromack, W. Denison, et al. Ecological characteristics of old-growth Douglas-fir forests. USDA Forest Service General Technical Report PNW- 1 18. Pacific North-west Forest and Range Experiment Station, Portland, Oregon. 1981.

Notes: This US Forest Service report defines the characteristics of old-growth Douglas fir forest ecosystems based on four structural components. The report utilizes photography and diagrams to illustrate the key characteristics of these old-growth forest ecosystems and identify distinctions between old-growth and second-growth forests. This report is a great example of how photography and images can be used to characterize different ecosystems and define their key features and spatial composition (similar to GBPM's "keywords") for monitoring later on or for other uses.

Global Change Research Program. The Changing Alpine Treeline Ecotone of Glacier National Park. West Glacier, MT:USGS. 1999.

Notes: A general information type report to introduce glaciers, alpine areas, and tree line to the general public. It is primarily focused on Glacier National Park. The report discusses some of the common disturbances to alpine areas, and includes a section on how alpine treeline and glaciers have changed and why such changes are significant. To identify what changes have occurred and what changes have not occurred, the report compares photographs from the early 1900s to photographs from the late 1990s.

Gorman, James. Yosemite and the Invention of Wilderness. New York Times, 2003.

Notes: This is a newspaper article on the collaboration between Rebecca Solnit and Mark Klett to rephotograph landscape photographs of Yosemite National Park from the 19th and 20th centuries. The article briefly describes some of the history of Yosemite and the conflicts between European settlers and Native Americans. It talks about the idea and role of wilderness in the way European settlers portrayed nature and the significance that humans were not to be part of that picture of nature.

Hall, Frederick C. Variation in Shrub and Herb Cover and Production on Ungrazed Pine and Sagebrush Sites in Eastern Oregon: A 27-Year Photomonitoring Study. USFS. PNW-GTR-704: 1-44, 2007.

Notes: A study of four different plant communities in the Blue Mountains of central Oregon to inform range condition guides. Compares 27 years of precision repeat photography in conjunction with field data to measure yearly fluctuations in canopy cover and herbage production. The study utilizes color comparisons to detect changes in plant nutrition and notes tree growth, sapling growth, and erosion.

Hall, Frederick C. Emigrant Creek Cattle Allotment: Lessons from 30 Years of Photomonitoring. USFS. PNW-GTR-639: 1-37, 2005.

Notes: A study of a cattle allotment northwest of Burns, Oregon. Compares 30 years (1975-2005) of precision repeat photography taken three times a year to measure impacts on riparian areas from cattle grazing as well as flooding and beaver presence. The study utilizes grid analysis and temporal variation in sampling to detect effects of altered an grazing system and other environmental factors.

Hall, Frederick C. Photo Point Monitoring Handbook: Part A--Field Procedures. Gen. Tech. Rep. PNW-GTR-526. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 1-48, 2002.

Notes: Guidelines and methods for documenting change in vegetation and soil through repeat photography. This document discusses field procedures. There is also Part B (see below) that is on concepts and office analysis. This handbook is mainly focused on photo points where the distance from the subject is always known, and permanent markers are placed in each photo point. This handbook is still useful to the ecoregional photo monitoring project because it offers useful principles and methodologies to consider. The end of this handbook is missing from pages 34-49.

Hall, Frederick C. Photo Point Monitoring Handbook: Part B--Concepts and Analysis. Gen. Tech. Rep. PNW-GTR-526. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 49-134, 2002.

Notes: This is an extensive handbook outlining the methods for documenting changes in soil and vegetation through repeat photography. This document reviews basic concepts and procedures for analyzing repeat photographs, discusses primarily non-digital equipment for repeat photography, and suggests methods for recording and archiving images and data. There is also Part A (see above) that reviews repeat photography field procedures.

Hall, Frederick C. Ground-Based Photographic Monitoring. Gen. Tech. Rep. PNW-GTR-503 Portland, OR:USDA Forest Service, Pacific Northwest Research Station. 1-340, 2001.

Notes: This is an extensive and lengthy handbook on ground-based photographic monitoring. It covers two types of ground-based photographic monitoring: comparison photography, and repeat photography. The handbook also provides guidelines and specific tips on how to set up the photo points, equipment, and documentation procedures. It is lengthy, but may be useful for reference on specific methodologies or questions (check the table of contents).

Hart, Richard H. and William A. Laycock. Repeat photography on range and forest lands in the western United States. Journal of Range Management 49:60-67, 1996.

Notes: This is a bibliography of 175 publications using repeat photography--intervals between photographs vary between over a century and less than a year. There is a short introduction at the beginning describing

spectrum of studies included in the bibliography. The references are focused on studies in the Western U.S.

Hastings, J. R. and R. M. Turner. The changing mile: An ecological study of vegetation change with time in the lower mile of an arid and semiarid region, Tucson, AZ: University of Arizona Press, 1965.

Notes: The book focuses on how humans and climate have played a role in altering the arid SW U.S. and NW Mexico. The authors used two methods to analyze the changes: 1) Using historical records of vegetation and climate; 2) Using historical repeat photography. In the preface they give some description of the methods they used to take pictures. Chapters 4-6 (pages 49-274) present a series of photograph pairs with some description and analysis.

Higgs, Eric, Sandy Campbell, David Cruden, Ian MacLaren, Jeanine Rhemtulla, Ron Hall, Ellen MacDonald, Samantha James, Nicola Miller, Jenaya Webb, Patricia Bailey, Gaby Zezulka-Mailloux, R. E. Stevenson, P. J. Murphy, and Rob Watt. The Bridgland Repeat Photography Project. 2004. http://bridgland.sunsite.ualberta.ca/

Notes: The Bridgland project was formed to retake the 735 photographs that M. P. Bridgland took in the early 1900s in Jasper National Park, Canada. This reference gives some background information on M. P. Bridgland, and then describes the core projects which are studying landscape change in Alberta, Canada--abstracts or descriptions of each project listed.

Hockings, Marc. Evaluating Protected Area Management: A review of systems for assessing management effectiveness of protected areas. Queensland, Australia:The University of Queensland. 2000.

Notes: This paper reviews 31 methodologies that are used to evaluate the management and effectiveness of protected areas. Hockings explores such issues as who should conduct evaluations, how they should conduct them, current problems with the ways evaluations are carried out, and types of data that are collected for helping the evaluation. This paper is related to repeat photography in a general sense since repeat photography is being used as a monitoring tool to measure the success of TNC's programs.

Hockings, Marc, Sue Stolton, and Nigel Dudley. 2000. Evaluating Effectiveness: A Framework for Assessing the Management of Protected Areas. Best Practice Protected Area Guidelines Series. Cambridge, U.K.: IUCN.

Notes: This reference provides a suggested framework on evaluating effectiveness of management of protected areas. It outlines why it is important to evaluate and monitor protected areas, presents a toolkit for making an evaluation, and suggestions for applying the framework at different scales (site level, national, international, global). Case Studies are presented from different countries including Australia, the Congo Basin, Central America, and South America.

Hockings, Marc, Sue Stolton, Nigel Dudley, and Jeff Parrish. Evaluating Effectiveness Training Workbook (Book 2): The Enhancing our Heritage Toolkit. UNESCO/IUCN. 2001.

Notes: This is a 136 page document that gives some background information on "Enhancing Our Heritage Project" sponsored by UNESCO, IUCN, UNF, provides a description of the World Commission on Protected Areas framework for assessing management effectiveness of protected areas, and an assessment of methodologies used to collect information used for assessment. The goal of this toolkit is to help World Heritage Sites and protected areas in general assess management effectiveness.

Hockings, Marc. Evaluating Management of Protected Areas: Integrating Planning and Evaluation. Environmental Management 22 (3):337-345, 1998.

Notes: This paper proposes a method for evaluating the management of protected areas. It is focused on the case study of Fraser Island World Heritage Area in Australia. Hockings emphasizes the need for planning and evaluation to be linked.

Howery, Larry D. and Peter Sundt. Using Repeat Color Photography as a Tool to Monitor Rangelands.

Rangeland Management:55-64, 2001.

Notes: This reference is focused on using repeat photography to monitor rangelands. It describes how to set up photo-plots, document the photo information, and provides general recommendations/advice on setting up repeat photography for monitoring purposes.

Ives, Jack D. Landscape Change Based on Repeat Photography of Northwestern Yunnan and its Relevance to the Himalaya Hindu-Kush Region. 1997. http://www.arl.arizona.edu/ispe/lucc_hkh.html

Notes: From the International Workshop on Dynamics of Land-Use/Land-Cover Change in the Hindu Kush—Himalaya. This is a summary of the presentation made at the workshop on the importance of repeat photography to understanding land-use and land-cover change in NW Yunnan. Some background information is given on Joseph Rock, and a study is proposed to form a more systematic archive of historical and present-day photographs and to combine the analysis from repeat photography with satellite imagery and computerized mapping. The study was proposed to occur through ICIMOD.

Liniger, H.P., R. Mekdaschi Studer, C. Hauert and M. Gurtner. 2011. Sustainable Land Management in Practice – Guidelines and Best Practices for Sub-Saharan Africa. TerrAfrica, World Overview of Conservation Approaches and Technologies (WOCAT) and Food and Agriculture Organization of the United Nations (FAO)

Notes: Prepared by WOCAT and coordinated by the FAO, this document presents 13 major groups of SLM technologies and approaches based on scientific, technical, practical and operational knowledge. The technologies are presented in 47 regional case studies with aim of boosting adoption of SLM on the African continent.

Lassoie, J.P., R.K. Moseley, and K. E. Goldman. 2006. Ground-based photomonitoring of ecoregional ecological changes in northwestern Yunnan, China. pp. 140-151. In: C. Aguirre-Bravo, P.J. Pellicane, D.P.; Burns, and S. Draggan. (eds.) Monitoring Science and Technology Symposium: Unifying Knowledge for Sustainability in the Western Hemisphere. 2004 September 20-24; Denver, CO. Proceedings RMRS-P-42CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 990 p. (available electronically at: http://www.fs.fed.us/rm/pubs/rmrs_p042.html)

Notes: Based on results from a collaborative ecoregional conservation assessment for two adjacent ecoregions in northwestern Yunnan, Hengduan Mountains and the Nujiang-Lancang Gorge, visual indicators obtained from photographs generated from a forward sampling ground-based, photomonitoring methodology designed around a high quality digital camera and a comprehensive database management system are used to assess the threat status from five key ecosystem conservation targets. A full description of the methodology reveals how The Nature Conservancy (TNC) has been using historical repeat photography to document ecological changes in northwestern Yunnan Province as part of its conservation planning efforts in China.

Lord, Matthew Alan. Documenting Landscape Change Using Repeat Panoramic Photography. Association of American Geographers. Illustrated Paper Session: Environmental Monitoring and Change I, 2003. (Abstract)

Notes: This reference is an abstract from the 2003 annual meeting of the Association of American Geographers. Lord discusses how repeat photography can be used to monitor land-use change outside of Phoenix, Arizona. He focuses on how traditional repeat photography can be improved and more effective if used with GPS, GIS, and with digital panoramic photography.

Manier, Daniel J. and Richard D. Laven. Changes in Landscape Patterns associated with the persistence of aspen on the western slope of the Rocky Mountains, Colorado. Forest Ecology and Management 167:263-284, 2002.

Notes: This article used repeat photography covering 80-100 year time span to conduct qualitative and quantitative analyses of changes in forest cover. The study combined use of repeat photography with GIS and remote sensing to perform quantitative analysis. Used 3 landscape metrics: total relative cover, mean relative *patch size, and number of patches per vegetation type. This study might be useful for thinking about how to incorporate quantitative and statistical analyses into the ecoregional photo monitoring project.*

Marzolff, I., Ries, J.B., Poesen, J. Short-term versus medium-term monitoring for detecting gully-erosion variability in a Mediterranean environment. Earth Surface Processes and Landforms 36: 1604-1623. 2011.

Notes: This study used aerial repeat photography to monitor gully erosion in Spain between 1995 and 2008. The study used aerial photography as ground-based monitoring was made difficult by gully banks shifting from erosion after heavy rainfall events. The study used retrospective images for medium-term analysis (i.e. historical repeat photography). Unmanned kites, blimps, and planes captured photographs from 50-300m above ground. The study confirmed that short-term monitoring data was not representative of long-term gully development and that medium-term monitoring of both headcut and sidewalls is necessary for describing the development of a gully.

McDonald, A. The Five Foot Road: In search of a vanished China. 1995. San Francisco: Harper Collins West.

Notes: A book recounting the journey that George Ernest Morrison took in 1894 across southern China to Burma. McDonald attempts to uncover the changes that have occurred on Morrison's route by looking at both Morrison's writings and the photographs from Jenson (a Danish engineer in Kunming who met Morrison). Most of the comparisons McDonald makes are socio-cultural—not ecological.

Michael, P., Mathieu, R., Mark, A.F. Spatial analysis of oblique photo-point images for quantifying spatio-temporal changes in plant communities. Applied Vegetation Science 13 (2): 173-182, 2010.

Notes: This article addresses the question of whether spatial analytical techniques can be used to extract quantitative measurements of vegetation communities from ground-based photo-point images. They used a grid technique and an object oriented technique, which used color and textural patterns, to map images for vegetation abundance and cover. Both techniques worked well, although the grid technique was more efficient and accommodated more image types. The techniques required some manual classification and strict protocols for taking the photographs.

Mills, Thomas J., Thomas M. Quigley, and Fred J. Everest. Science-Based Natural Resource Management Decisions: What are they? Renewable Resources Journal 19 (2):10-15, 2001.

Notes: This article offers guidelines on how to ensure science plays a larger role in decision making about natural resource management. Mills et. al. uses two case studies from the Tongass National Forest and the Columbia River Basin to illustrate their guidelines.

Moseley, Robert K. 2003. Ninety years of landscape change in the Tibetan borderlands of China.

Notes: Moseley looks at landscape changes and trends using repeat photography over a 90 year time scale in NW Yunnan. He repeated 38 photographs from Ward and Rock who explored the region between the years 1913-1923. Moseley looks at trends in forest cover, agriculture, glaciers, settlements, arid shrublands, grazing on alpine pastures, and invasive species.

Noss, R. F. Indicators for Monitoring Biodiversity – a Hierarchical Approach. Conservation Biology 4 (4):355-364, 1990.

Notes: Noss defines biodiversity and offers criteria and indicators that should help scientists and policy makers realize what biodiversity is, and how it can be monitored. He organizes the attributes of biodiversity into a nested hierarchy. At the end of the article Noss offers an example of how a monitoring program of biodiversity could be implemented.

Nusser, Marcus. Change and Persistence: Contemporary Landscape Transformation in the Nanga Parbat Region, Northern Pakistan. Mountain Research and Development 20 (4):348-355, 2000.

Notes: This article describes the use of repeat photography spanning 60 years to look at vegetation changes and the development of land use patterns in the NW Himalayan region of Pakistan. Changes are attributed *to an expansion of cultivated areas, an increase in settlement size, intensified irrigation, and degradation of certain species of forests. The article gives an introduction to the use of repeat photography to monitor changes in land cover and land use, and it includes numerous photo-pairs and analysis of the changes.*

Nusser, Marcus. Understanding cultural landscape transformation: a re-photographic survey in Chitral, eastern Hindukush, Pakistan. Landscape and Urban Planning 57:241-255, 2001.

Notes: This article uses repeat photography spanning a 30 year time period to monitor changes in land-use and land-cover in the high mountains of Chitral. The article focuses on the need to bring both natural and social sciences together to examine landscape changes. Nusser proposes that repeat photography is a methodology that can be used to bridge natural and social science perspectives together. The study focuses on irrigated fields in villages, and many of the changes in the landscape are found to be due to an increase in population and thus an increased size of villages and cultivated areas (although individual cultivated areas actually decreased in size).

Nyssen, J. et al. Desertification? Northern Ethiopia rephotographed after 140 years. Science of the Total Environment 407: 2749-2755. 2009.

Notes: This analysis used historical photographs taken by Great Britain during their military expedition in 1868 to Northern Ethiopia. The study assessed the status of vegetation and land management during the two periods (i.e. 1868 and 2008). The study showed a significant improvement in vegetation cover, with the introduction of eucalypt woodlands and regeneration of indigenous trees and shrubs. The study also showed an improvement in farmland management of soil and water.

O'Connor, Patrick J. and Anthelia J. Bond. Maximizing the effectiveness of photopoint monitoring for ecological management and restoration. Ecological Management & Restoration, 8 (13): 228-234, 2007.

Notes: Discusses the benefits and limitations of using photo-monitoring to track ecological management and restoration.

Oliver, Chadwick D., J. P. Kimmins, Howard W. Harshaw, and Stephen R. J. Sheppard. Criteria and Indicators of Sustainable Forestry: A Systems Approach. 2004, p. 73-93.

Notes: This reference is very theoretical. It discusses what sustainable forestry means, how to organize and prioritize the different processes and activities that occur in forests, what criteria should be considered in sustainable forestry, and how the suggested criteria and indicators can be incorporated into decision-making.

Orchard, Charles and Chris Mehus. Management by Monitoring: Land EKG monitoring approach helps variety of users assess rangeland health. Rangelands 23 (6):28-32, 2001.

Notes: The goal of this study was to come up with a standard method for monitoring rangeland resources. EKG is a tool developed to "evaluate and graphically portray land health information based on a rapid assessment of ecological processes". The EKG tool monitors 22 indicators that are related to basic ecosystem processes such as the mineral cycle, water cycle, succession, and energy flow. The article gives detailed information on the development of the EKG tool and how it can be put into practice.

Paar, Philip and Jurgen Peters. Visual Elements and Structures of Landscapes in Brandenburg (Germany) - Development of an Image Database and Photo Library. Muncheberg, Germany:Grano Project. 1999. http://www.zalf.de/grano/publikation/paar_etal1999.pdf

Notes: A study from Germany focusing on photography used for monitoring landscapes. The article explores how to organize photo archives and develop an image database that is easily searchable. This article is relevant and helpful for thinking about organization of images.

Peterson, DJ, Susan Resetar, Jennifer Brower, and Ronald Diver. Forest Monitoring and Remote Sensing: A survey of accomplishments and opportunities for the future. Washington DC:RAND Science and Technology Policy Institute. 1999.

Notes: This report looks at methods of monitoring forest management and describes the role of remote sensing in data collection. It has a couple of case studies in appendices in Brazil and Canada, but the report is primarily focused on the use of remote sensing in forest monitoring activities in the U.S.

Pickard, John. Assessing vegetation change over a century using repeat photography. Australian Journal of Botany 50:409-414, 2002.

Notes: Introduction to the use of repeat photography to assess vegetation change. Limitations of repeat photography are also discussed. Reviews American experience with repeat photography, and also discusses how repeat photography has been used in Australia.

Rogers, Garry F, Harold E. Malde, and Raymond M. Turner. Bibliography of Repeat Photography for Evaluating Landscape Change. Salt Lake City, University of Utah Press: 1984.

Notes: An extensive bibliography of studies that use repeat photography to evaluate landscape change. Includes an introduction to repeat photography and methodology of repeat photography.

Sheppard, Stephen R. J. Beyond Visual Resource Management: Emerging Theories of an Ecological Aesthetic and Visible Stewardship. 2001, p. 149-173.

Notes: This article is very theoretical, but, put simply, it explores the correlation between visual quality and forest sustainability. Sheppard looks at the relationship between aesthetic values and indicators of sustainability. In other words, if it looks good to the public is it necessarily sustainable and vice versa? This article may be too theoretical to be of much use to the ecoregional photo monitoring project, but since it is focused on the importance of using visual resources for monitoring resource management, it may have some relevance—especially when we are considering what indicators to monitor in our images. Reading the conclusion of this article may help to get a real sense of the subject matter.

Skovlin, Jon M., Gerald S. Strickler, Jesse L. Peterson, and Arthur W. Sampson. Interpreting Landscape Change in High Mountains of Northeastern Oregon from Long-Term Repeat Photography. Portland, Oregon:USDA Forest Service, Pacific Northwest Research Station. PNW-GTR-505:-78, 2001.

Notes: Repeat historical photography study spanning the years 1925-1999 in three mountain ranges above 5,000 ft in NE Oregon. The study looked at changes in vegetation and land-cover due to changes in land-use such as the alteration of wildlife habitat, tree encroachment, effects of fire suppression, insect outbreaks, disease epidemics, and human impacts such as grazing. Includes a literature review at the beginning of the report.

Start, A. N. and T. Handasyde. Using photographs to document environmental change: the effects of dams on the riparian environment of the lower Ord River. Australian Journal of Botany 50:465-480, 2002.

Notes: Study uses repeat photography from the years 1952 to 1990 to assess changes to the riparian environment due to the construction of dams in Western Australia. This article shows that due to a lack of other data sources and information, repeat photography can offer important insights into landscape and vegetation change. At the same time the article points out that repeat photography still has numerous limitations as a monitoring tool on its own.

Student Watershed Research Project/Saturday Academy of Oregon. 2004. Photo Point Monitoring Instructions.

Notes: Step-by-step instructions on how to do photo point monitoring.

Sturm, Matthew, Charles Racine, and Kenneth Tape. Increasing Shrub Abundance in the Arctic. Nature 411, 2001.

Notes: A brief, one page article on the effect of the warming of the Alaskan Arctic on shrub abundance. The study uses historical and modern aerial photography between 1948 and 2000. A total of 66 photo comparisons were made.

United States Forest Service. 1994. Vegetation changes on Mani-La Sal National Forest: A photographic study using comparative photographs from 1902- 1992. USFS.

Notes: This study uses comparative photography to monitor the effects of applied natural resource management and natural ecological processes over 90 years in the Manti-La Sal National Forest in Utah. Photographs from the first half of the century (1902-1960s) were compared with repeat images taken in the 1990s. The study concluded that 90% of the locations photographed showed improved vegetative conditions and that the images would be useful for monitoring potential ecological issues in the future. The study also cites historical events that helped explain the changes seen in the image comparisons.

United States Department of Agriculture. 1996. Criterion and Indicator: Conservation of biological diversity. http://www.fs.fed.us/land/sustain_dev/sd/criter1.htm

Notes: This reference discusses indicators of biodiversity, whether they can be quantified, and whether the data is available. This report was put together by the USDA Forest Service, therefore much of the information is focused on the U.S.

United States Geological Survey. 2003. Repeat Historical Photography of Twentieth Century Vegetation Change in Wyoming and Montana. The University of Arizona Desert Laboratory, USGS. http://wwwpaztcn.wr.usgs.gov/wyoming/rpt_ground.html

Notes: Introduces ground-based repeat historical photography and references other studies to show its significance to monitoring environmental changes. Offers sources for historical photographs. Provides a short bibliography of repeat photography references. Gives some examples of repeat photograph pairs which show changes in vegetation cover.

United States Geological Survey. 2004. USGS Glacier National Park Repeat Photography. http://www.nrmsc.usgs.gov/research/global

Notes: USGS scientists use repeat photography to help assess the effects of global climate change on glaciers. A series of repeat photos available on the web as well as updates of ongoing studies. The document in file is a one page description of the kinds of studies occurring, and where these studies can be found online.

Vankat, J. L. and J. Hlajor. Vegetation changes in Sequoia National Park, California. Journal of Biogeography 5:377-402, 1978.

Notes: The study uses repeat photography, historical descriptions, and age-- population structure of the trees in Sequoia National Park to interpret vegetation changes. The article focuses on 21 vegetation types. There are some photographs in the article but they are poor quality since they are photocopied. The study find that the primary cause of vegetation changes is the land use practices of western people such as livestock grazing and changes in fire frequency.

Webb, Robert H., Diane E Boywer, R.M. Turner. Repeat Photography: Methods and applications in the natural sciences. Island Press: Washington, D.C. 2010.

Notes: This book provides a solid overview of repeat photography and its applications in the sciences with contributions from several authors. The first section offers excellent background, history, methods and techniques of repeat photography. Moreover, 18 chapters offer detailed examples of repeat photography being used in geosciences, population ecology, ecosystem changes, and cultural studies worldwide.

Webb, Robert H., Raymond M. Turner, Kathryn A. Thomas, Todd C. Esque, and Kristin H. Berry. Climatic Fluctuations and Desert Vegetation Response in the Southwestern United States. Uncertain Journal Name, 2002. (Abstract)

Notes: Abstract from the 27th Annual Meeting and Symposium of the Desert Tortoise Council in 2002. The abstract discusses the use of repeat photography to monitor long-term changes in desert vegetation. The abstract points to the limitations of satellite imagery and aerial photography, and suggests that repeat *photography can be used instead to assess changes in plant size, density and species. The abstract makes reference to previous studies that have focused on desert vegetation and used repeat photography.*

Webb, Robert H. and Diane E. Boyer. Changes in Riparian Vegetation in Arizona: Repeat Photography at Gaging Stations. USGS: Arizona Water Resources Team. USGS, 2004. http://az.water.usgs.gov/rwebb/changes.html

Notes: This reference is an introduction to a USGS report. Numerous photos have accumulated from monitoring studies at gaging stations since the early 1910s, and a USGS team has decided to collect these photos and use repeat photography to assess the changes and status of riparian vegetation around these gaging stations. The changes they found included: large increases in native and non-native vegetation at most sites, complete elimination of riparian vegetation at some sites, channel down-cutting, lateral channel changes, and deposition of new fluvial terraces.

Appendix B: Ground-Based Photo-Monitoring Equipment

Camera Options

There are three main types of cameras that can be used in GBPM surveys: a DSLR, a point and shoot, and a cell phone camera.

Digital Single Lens Reflex (DSLR) Cameras

Like its film counterpart, a digital single lens reflex camera (DSLR) is characterized by a mirror and pentaprism that allows the photographer to frame an image through the lens, which then rapidly retracts when the shutter button is pushed, opening the shutter and allowing light to strike the camera's light sensor (Figure 6). The mirror returns equally fast immediately after the exposure – the entire process taking a fraction of a second depending on shutter speed (e.g., 1/30, 1/125, 1/500 of a second). Most photographers prefer DSLRs because of the ease of accurate image framing, 'instantaneous' image capture, and exchangeable lenses. Such characteristics provide the greatest flexibility and possibilities, but also come with financial and complexity costs.

A high quality DSLR camera can be a great asset to a GBPM project because it is important to capture as much detail as possible in an image, thus allowing for accurate identification of important elements (i.e. keywords) in the images. DSLRs also have an advantage with regard to image resolution (how much detail is visible) and color trueness (how well the colors in the images match reality). For instance, high-resolution images have the potential to allow species to be identified within an image even when the image was taken from a far distance. Higher resolution, however, also means the sensor is more costly to manufacture, thus making the camera more expensive.

The physics of light capturing sensors is discussed briefly below (see Aspects of a Digital Photo), but what is relevant when selecting a camera is the size of the overall sensor and the number of light-capturing cavities (i.e., photosites) on it. In general, a larger sensor with more and smaller light gather sites means higher resolution that will produce clearer, more finely detailed images that can enhance the utility of the resulting photographs (Table 1).

A modern DSLR carries a sophisticated on-board 'computer' that automatically interprets complex light conditions,

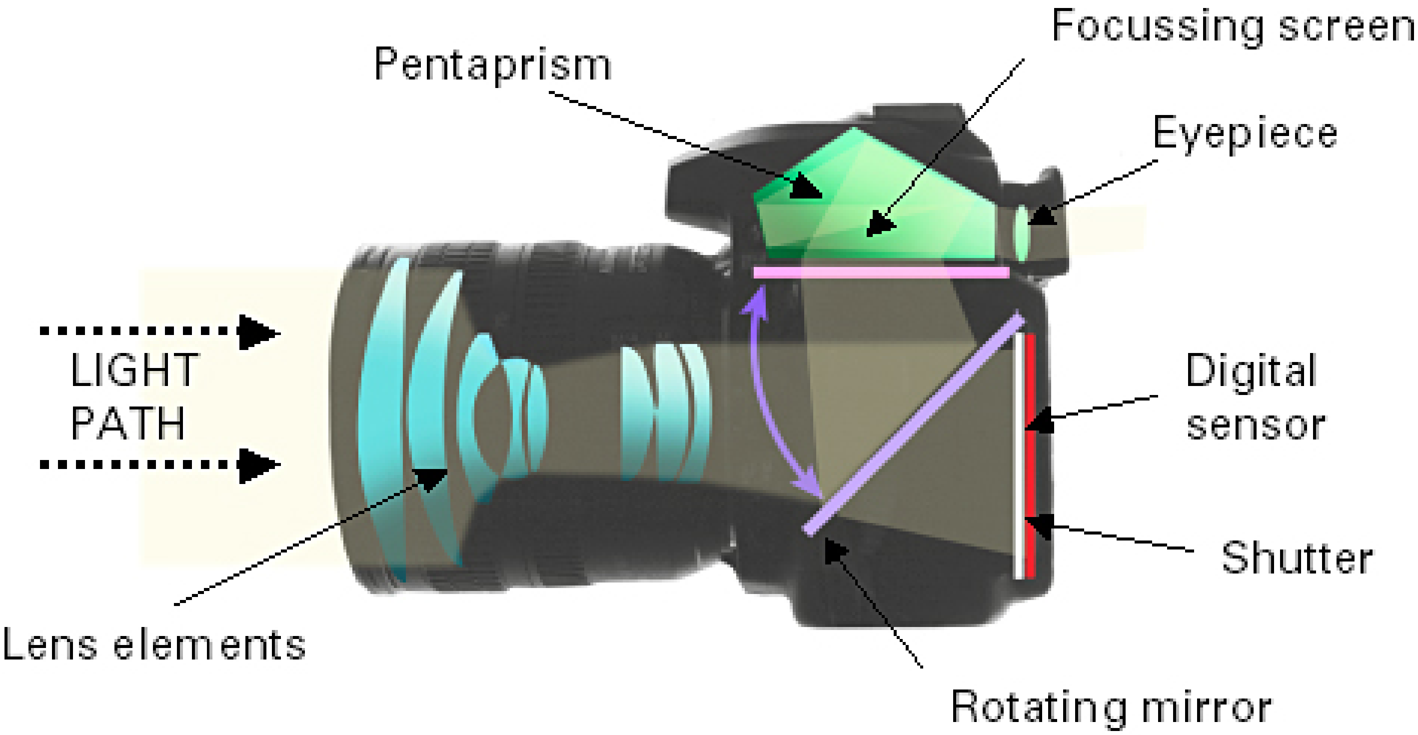

Figure 30. Digital single lens reflex camera cut-away diagram (Illustration: www.jiscdigitalmedia.ac.uk)

sets the proper exposure by adjusting the camera's shutter speed and connecting electronically with the lens to set a corresponding aperture, focuses the lens, and takes the picture almost instantaneously once you push the button. They are remarkably accurate and under most lighting conditions produce images of excellent quality.

DSLRs also have the option to function in manual mode, giving the photographer complete control over apertures, shutter speeds, focusing, and depth of field. This can lead to better-exposed images under poor light conditions (e.g., under a forest canopy). Obviously, operating in manual mode requires more photographic knowledge and skills, but regardless of the exposure mode selected the GBPM photographer must become familiar and proficient with the camera's operation. The first step in this learning process is RTM – read the manual, and then practice, practice, practice!

Point and Shoot Cameras

Mid-quality Point and Shoot Cameras (P&S) are a less expensive option for image capture, yet provide decent quality images with relatively simple, easy-to-learn operation. As technologies improve so do the image resolution capabilities of mid-range cameras. Today, point and shoot camera image resolution typically ranges between 5.1-16.1 megapixels per inch. The price of a point and shoot ranges between $50-$200. While image resolution can compete with some DSLR cameras, point and shoot cameras have limited manual controls for taking pictures. Most rely on automatic exposure settings and cameras that have manual settings are often limited to only a few controls.

Cell Phone Cameras

As cell phones become more common, especially among rural communities, the use of Cell Phone Cameras can be a great asset for GBPM surveys. Image resolution from cell phone cameras can vary greatly. While basic cell phone cameras can be as little as 1.1 megapixels per inch, high-end smartphone cameras can range from 5.1 up to an incredible 41 mega-pixels. These high-end models are often equipped to geo-tag the images with latitude and longitude information according to the network connection. Currently cell phone cameras rely entirely on automatic exposure settings although some high-end models can alter color tints and brightness and contrast controls.

The primary asset of cell phone cameras being used in GBPM surveys is that most people now own them. This opens up the possibility for many people to participate in GBPM surveys without added equipment costs and subsequently opens up the possibility for increased discussion about landscape changes amongst the community.

Additional GBPM Equipment

Geographic Position System Device

A Geographic Positioning System (GPS) device ensures accurate geo-referencing of repeat images. Geo-reference data includes latitude, longitude, elevation, and UTC time (Coordinated Universal Time). This data is critical for the precise relocation of photo-points in the future.

Hand-held GPS units, like those made by Garmin, are common tools found in many offices and often serve many purposes. Hand-held units can effectively record geo-reference data at each photo-point and often have more functional applications like satellite maps and route recording. There are also GPS accessories that are specifically compatible with many kinds of cameras. Mounted onto a camera, these units will record the geo-reference data of a photo-point within an image's metadata. While these accessories are often expensive, the benefit of using a camera compatible GPS unit is its consolidation of data into a single file (the image file).

GPS units can streamline future retakes and help in the data organization process. GPS units can be especially helpful if you will be creating your GBPM database using GIS; a simple upload of the photo-points onto your computer will place photo-points in your GIS map.

If you are limited financially, a GPS device is not entirely necessary so long as you have adequate, large-scale maps and a solid understanding of where you are in relation to the map. In this case, a simple marking on the map to indicate each photo-point can suffice for data organization and future retakes. However, this method may prove difficult for future retakes as it may take more time to relocate a photo-point location.

Compass

A compass is another tool that is especially useful for GBPM projects. Recording the compass bearings--the direction (in degrees) that the camera is facing when you take an image--can ensure that future repeats will be accurately retaken to effectively portray landscape changes. Magnetic compasses are relatively inexpensive and simple to use. Compasses are not essential if stable landmarks are present (i.e. landmarks that won't change over time, such as large mountains or horizon lines), however having a compass will absolutely increase the accuracy of your GBPM survey.

Tripod

Although it is not critical piece of equipment, a Tripod can be a helpful tool to have with you in the field. Tripods can help stabilize the camera during field work, which is especially helpful during low-light situations when the exposure settings are slow. Tripods will also help maintain a consistent distance between the ground and the camera and help you keep the camera level, improving the accuracy of future retakes. Moreover, many tripods come with bubble levels (see more below) installed on them so that you can ensure that the bottom of the image frame is parallel to the horizon.

Tripods range in size and durability, but there are many inexpensive options that are suitable for GBPM surveying. Be sure when selecting a tripod that the mount mechanism is compatible with your camera. Most DSLR and point and shoot cameras will have a simple screw mount specifically built for tripods. Cell phones will likely need an additional attachment or a specialized tripod. Useful specifications and additional accessories to look for when selecting a tripod include transportability (e.g. collapsible legs, weight, and size), the height of the tripod at its full extension, and a bubble level on the tripod.

Bubble Level

A bubble level is a small accessory that can add a lot of precision to a GBPM project. Levels are typically small tubes or circles that are filled with mostly liquid and a small amount of air. When you tilt the level, the bubble of air will shift, rising to the highest point. Line markings or concentric circles on the level will indicate whether or not the camera or tripod is stable and parallel to the horizon. Using a bubble level can help standardize GBPM image perspectives and ensure that future retakes will be accurately aligned to effectively portray landscape change. For instance, when photographing a sloped hillside, if you capture an image with a leveled camera the image will accurately depict the slope of the hillside, whereas if the camera is tilted, the slope will be recorded at an inaccurate angle. Some levels are can be attached to the top of a camera's flash mount, others come installed on tripods. Some cameras even come with a digital level installed in the settings menu.

Exposure

We will discuss several camera settings that can be adjusted to manipulate the resulting image. The best way to truly understand the following settings is to experiment and practice with your camera. Try taking pictures of the same subject under different settings. With a little practice, you will begin to notice how variations in each setting will affect the resulting photographs.

Overview

Exposure is the amount of light that reaches the camera sensor and is differentiated by the shutter speed, aperture, ISO, and light conditions where you are photographing. Manipulating any of these aspects will change the resulting image. Too much light will result in a very bright, white image (over-exposed); too little light will result in a very dark, black image (under-exposed). The correct exposure will result in an image that has enough contrast so that you can clearly see features within the image (see figure x below).

If you are using the manual settings on a DSLR or point and shoot camera, having the correct exposure is critical. Automatic exposure settings can be used, but can be frustrating to work with in high light or high-contrast conditions or in poor weather conditions. While we will describe their effects of different aspects that affect exposure below, refer to your camera's manual for specific instructions on making the following exposure adjustments.

Key Exposure Settings

Aperture

The aperture (also called an f/stop) is a measure of the width of the hole in the lens through which light passes to reach the light sensor within the camera. The relationship between the aperture number and the hole size is inverse, that is, the higher the aperture number the smaller the hole and thus, the less light that can reach the sensor (e.g. f/3.5 is a wide hole, f/22 is a narrow hole). Aperture affects the depth of field of an image or the depth of the area in an image that is in focus. A low aperture setting (e.g. f/2.8) will produce a narrow depth of field, meaning that a narrow portion of the image will be in focus. A high aperture setting (e.g. f/22) will produce a wide depth of field, meaning that a deep portion of the image will be in focus. Since clarity of all parts of the image are important in GBPM, the aperture should be set to the highest number possible (different camera types and lenses will have a different aperture range).

Shutter Speed

Shutter speed refers to the amount of time light is allowed to reach the light sensor in the camera. The shutter speed is measured in seconds or fractions of a second (e.g. 1/15 means one-fifteenth of a second, 1/5000 means one-five-thousandth of a second, 2" means two seconds). For low-light settings, a slow shutter speed (e.g. 2") is necessary to capture enough light to produce a well-exposed image. In high-light or bright light settings, a fast shutter speed (e.g. 1/500) is necessary. When the shutter is open, the light sensor will record everything that it senses. As such, if the camera moves while the shutter is open the resulting image will be blurry. Tripods reduce the risk of moving the camera while the image is exposing at a slow shutter speed. Outside conditions with adequate natural light typically require a fast shutter speed and thus the risk of a blurry image is low.

ISO

ISO is a measure of the sensitivity of the light sensor in the camera. The higher the ISO number the more sensitive to light the image sensor is and visa versa. A high ISO setting (e.g. 1600, 3200) is very sensitive to light and can take well-exposed images in dim lighting. Higher ISOs, however, often produce images with noise (grainy, spotting in the image) that can reduce the image's clarity and detail. Since the clarity of the image is important in GBPM, the ISO should be set to as low a number as possible (e.g. 100-400). This will ensure that the image is clear and finely detailed.

Exposure Presets

Different cameras will have different exposure presets that you can use for GBPM surveying. We will describe a few common presets here, but you should refer to your camera manual for more information.

Manual

Manual (M) exposure settings enable the photographer to independently set both the aperture and the shutter speed manually.

Shutter Priority

Shutter priority (S or Tv) exposure settings enable the photographer to manually set the shutter speed and the camera will automatically adjust the aperture for a correct exposure.

Aperture Priority

Aperture priority (A or Av) settings enable the photographer to manually set the aperture and the camera will automatically adjust the shutter speed for a correct exposure.

Automatic

Automatic or Programmed Auto (P) lets the camera adjust both the shutter speed and the aperture for the correct exposure.

Many digital cameras will come with a diverse selection of programmed auto settings specific to different subjects, such as action, landscapes, portraits, and macro. These settings take into account common attributes of subjects that require different exposure settings. For example, a photograph of a running cheetah or a moving car will require a fast shutter speed in order to get a sharp image, thus and action preset will prioritize use a fast shutter speed. In contrast, a picture of a landscape will have many features stretching a far distance, thus the landscape preset will prioritize a narrow (high) aperture for optimum depth of field. Refer to your camera's manual to see which presets are installed and how you can utilize them for GBPM.

Figure 31. Three versions of the same image taken with different exposures: under-exposed (left), correct exposure (center), over-exposed (right).

Aspects of Light

Although understanding light is extremely important to photographers, as it influences the entire workflow (i.e., from image capture and the use of artificial light sources or filters to image processing output), its comprehensive coverage is beyond the scope of this manual. A few general characteristics of light, however, are relevant to GBPM.

First, it is important to understand that the human eye only sees a portion of the electromagnetic spectrum arising from the sun, which gives rise to what we define as colors (i.e., violet to red; Figure 5). The proportion of these colors change during the day, which effect color quality. Landscape photographers often focus on the "golden hours," the few hours after sunrise and before sunset, because midday sun (approximately 10:00–14:00) has higher color temperatures (>5,000 oKelvin), that emphasize the blue portion of the electromagnetic spectrum (Figure 5), which produce blueish-white tints in photographs. Midday sun also increases contrast and causes harsh shadows that can be distracting. In contrast, morning and late-afternoon sun exhibits lower color temperatures (2,700–3,000 oK), pushing photographic colors toward the yellowish-white to red range. Although perhaps more artistically pleasing, such photographs also exhibit a 'softer' contrast, which may reduce details critical to GBPM. Hence, trade-offs need to be considered, but for GBPM images taken at midday in full light likely will produce the clearest, sharpest results.

Second, what we 'see' is actually just the color(s) that are not absorbed by an object. Hence, we see a red card because the red color wavelength is reflected from it; a white card reflects back the entire color spectrum, and a black card none. There are actually millions of discernible colors because everything we see is actually a combination of multiple colors with wavelengths varying from 380 (violet) to 750 nm (red). Hence, a 'green' leaf primarily reflects 495–570 nm (Figure 5), but can also have elements of the entire spectrum. Digital sensors may have trouble separating these tonal differences, which may make it difficult identify variations in vegetative patterns across a landscape. Hence, the value of these images to a GBPM project might be enhanced by using light modifying camera filters and/or appropriate image processing programs (i.e., Photoshop). These techniques will be discussed later in this manual.

Lastly, sensors in digital cameras, scanners, monitors, and printers (as well as development papers in wet-chemistry image processing) all 'see' colors differently from humans and from each other. This means that the digital image workflow process must 'calibrated' to assure accurate color matching, especially between the monitor used in image processing and the output printer. This will be discussed later in this manual.

White balance is a setting that regulates the color saturation and hue of an image's color spectrum. Different types of light sources (e.g. fluorescent light bulbs, direct sunlight, overcast skies) will emit different proportions and intensities of colors. This can cause the true whites in an image to be tinted a certain color (e.g. fluorescent lights typically tint whites a blue). White balance settings can account for and correct "discoloration" caused by different light sources. Most DSLR and point and

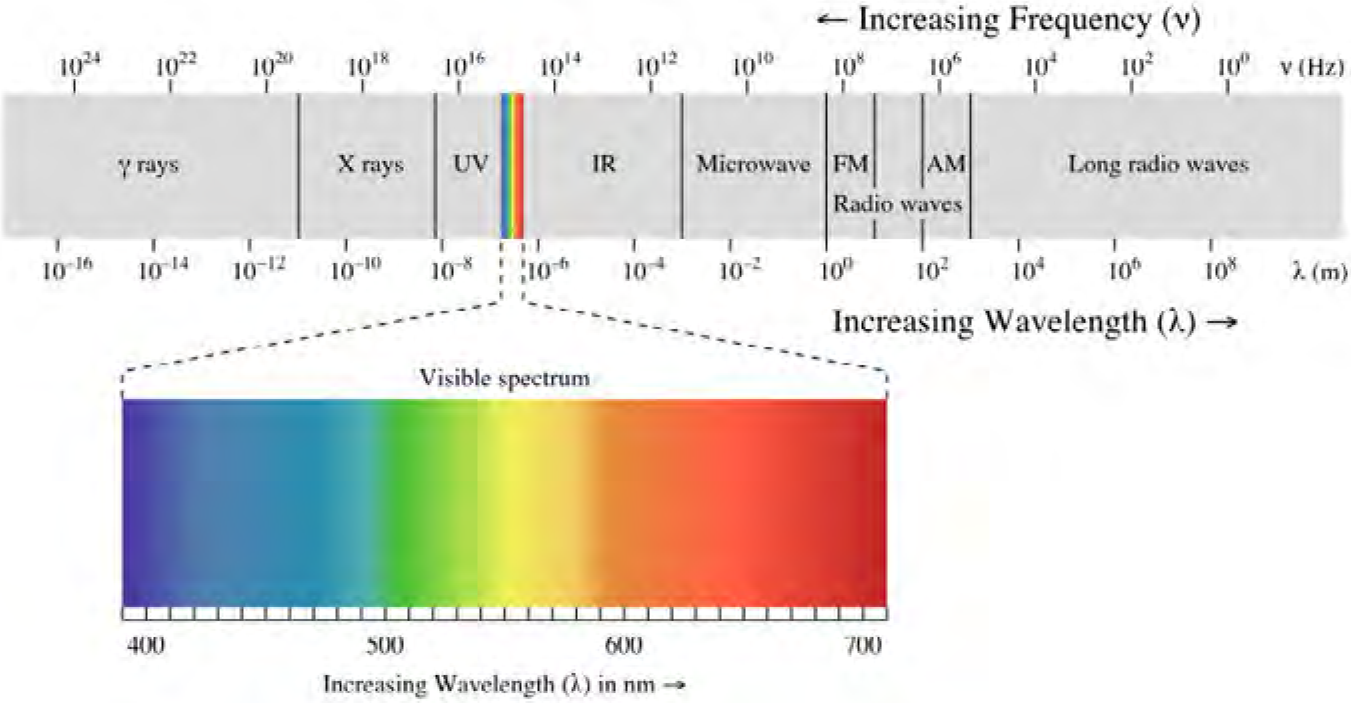

Figure 32. The color spectrum (www.upload.wikimedia.org/wikipedia/commons/thumb/f/f1/EM_spectrum.svg/787px-EM_spectrum.svg.png)

shoot cameras come with several white balance presets as well as a manual setting. Refer to you camera's manual for specific settings.

Aspects of a Digital Photograph

Raster image

A raster image or a bitmap, is an image that is composed of a dot matrix data structure (see figure x below). In digital photography, a raster image is composed of pixels, small squares with individual color properties.

Pixel

A pixel is the smallest element of a raster image. Each pixel contains individual color properties, typically proportions of a combination of basic colors depending on the color model used (see below). Viewed individually, a pixel is simply a small, monochrome square; viewed together, however, and the pixels create a recognizable image. The more pixels in an image, the less recognizable the individual pixels are and the more realistic the image appears.

Megapixels

A megapixel simply means one million pixels. In digital photography, megapixels are often used as a measure of the resolution of the resulting raster image, where more megapixels correspond to a higher resolution. Hence, a 16 MP camera means that each photo will have 16 million pixels composing the image.

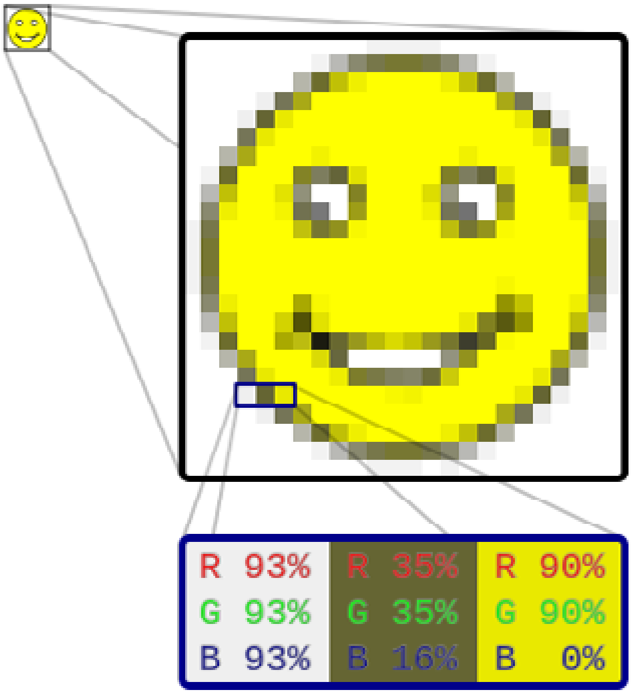

Figure 33. A raster image diagram (www.commons.wikimedia.org/wiki/File:Rgb-raster-image.svg)

Image file formats

Digital cameras can store images as different kinds of image file formats. Different file formats will store image data in different ways. For example, some formats, like JPEG, will compress an image's data, meaning that the light the sensor recorded is reduced and simplified. We will not explain the details of each image file format here, but we will introduce common formats and the differences related to GBPM.

JPEG

The name JPEG is simply an acronym for Joint Photographic Experts Group, the committee that created the JPEG standard, which defines how the image file is compressed into a raster image. The compression method simplifies and eliminates some of the original image data, like color variation or saturation. Once an image is compressed into a JPEG the data that is eliminated cannot be restored. The trade-off is essentially between image quality and storage space. A high amount of image compression will result in a small file size, meaning you can store more images on a memory card, however, when image data is lost the image quality will be reduced. Most point and shoot and DSLR cameras will store images as JPEG files unless otherwise specified. Many cameras will offer different levels of JPEG compression. One benefit of the JPEG file format is that it can be immediately opened on most computer viewing software and it is ready to be printed or edited on a bitmap or raster graphics editor, unlike camera RAW (see below). Most high quality JPEGs (low compression) are suitable for GBPM surveys.

RAW

A camera raw file is a minimally processed image file format, meaning that the data recorded by the image sensor undergoes very limited processing before it is stored. Raw image files are often called "digital negatives" because, like a film negative, they are not immediately ready to be viewed, printed, or edited; just as film negatives need to be processed to produce photographs, raw files need to be processed before they can be viewed as a normal image. The benefit of raw image files is that they will retain most of the image data that the sensor recorded. The drawback is that raw image files require more storage space and require specific software programs to edit and convert into formats that are ready to view, print and edit. Many professional photographers and GBPM surveyors opt for camera raw file format because it preserves important image data and enables higher quality post image-capture processing (e.g. Photoshop). While camera raw files formats are beneficial to GBPM because they retain true colors, they require a lot of storage space and additional processing time.

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