A Mobile System for Community Based Natural Resource Monitoring: A Case Study in the Sierra Madre, Chiapas

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Table 1 Glossary of Commonly Used Terms

Term	Definition
Aggregate Server	A website with a unique identifier where data is sent and stored.
Android	A mobile phone operating system.
CSV (.csv)	Comma Separated Value: A data format that stores tabular data in plain text format for easy transfer and storage. Most often used for data tables like Microsoft Excel.
Data Aggregation	In a mobile-based data collection system, multiple sources are collecting simultaneously. Data aggregation occurs when data is compiled together.
Database	A single location where information is stored.
Freeware	Software that is free to acquire, often called "Open source".
Google App Engine	A free service provided by Google that allows web developers to host a program on the Google server. The default location for an Aggregate server created by **ODK Aggregate** is **Google App Engine**.
Google Docs	A service provided by Google that allows users to store documents online including presentations word documents and **Fusion Tables.**
Google Fusion Tables	A service provided by Google that allows users to create data tables with location information with the goal of creating dynamic maps.
HTML	HyperText Markup Language: The main computer markup language for creating web pages.
Kobo PostProcessor	A **freeware** program created by a mobile-based health project that transforms data from **.xml** format to **.csv.**
XML (.xml)	Extensible Markup Language: A computer language format in which **Xforms** are written.

Mobile-Based Community Monitoring System	A data collection framework where community volunteers or park guards collect ecological data and systematically transform it into usable spreadsheets and maps for analysis using a mobile tool, like a cell phone.
Mobile-based data collection system	A data collection framework where multiple, often disparate users collect data and systematically transform it into usable spreadsheets and maps for analysis using a mobile tool, like a cell phone.
Open Data Kit (ODK)	Open Data Kit: A non profit run out of the University of Washington Computer Science Department and funded initially by Google. Their mission is to facilitate free mobile data applications.
ODK Aggregate	Open Data Kit Aggregate: A program created by **ODK** that launches a web-based database where data aggregation occurs. The default location for an Aggregate server created by ODK Aggregate is **Google App Engine.**
ODK Build	Open Data Kit Build: A program created by **ODK** that can create **Xform**s through a "Drag and Drop" process. ODK Build is web based and requires no downloading.
ODK Collect	Open Data Kit Collect: A program created by **ODK** that runs on any Android phone. ODK Collect is a survey program that uses **Xforms** and can send data remotely to an **Aggregate Server.**
ODK Community Forum	A web forum where **ODK** team leaders and users report errors, request features and discuss problems.
Xform	XML form: A web form written in .xml that creates a digital survey. Users interact with the survey by answering prompts provided.
XLS2XFORM	A freeware program produced by Open Data Kit that transforms a Microsoft Excel spreadsheet into and **Xform**. The Excel spreadsheet must follow certain rules.

Abstract

Community Based Natural Resource Monitoring (CBNRM) is a potential strategy to enable that Payment for Ecosystem Services (PES) schemes reach their intended effect of conserving ecosystem services like water provision, carbon sequestration and storage, and biodiversity conservation while strengthening small scale agroforestry systems that are indicated to both adapt to and mitigate climate change. However, CBNRM requires low-cost, easy to learn, replicable and adaptable methodologies that can be verified by independent third parties. Organizations like the Global Canopy Program and the Community Forest Monitoring Working Group are supporting the development of mobile data collection tools that have the potential to address many of the equity, efficiency and effectiveness concerns of the UN's Reducing Emissions from Deforestation and Forest Degradation program (REDD+) as well as provide additional benefits like empowering local communities with the tools to make informed decisions about their natural resources. We tested the viability of these mobile monitoring tools for data collection using Android compatible phones and the freeware program Open Data Kit (ODK) in the buffer zone of the El Triunfo Biosphere Reserve in the Sierra Madre of Chiapas, Mexico. In collaboration with the coffee cooperative Comon Yaj Noptic and a private coffee farm and reserve Finca Arroyo Negro, we carried out 190 sampling events with four community volunteer monitors between September and December 2011. Using this novel technology platform we tested 6 different monitoring targets: avian biodiversity point counts, above ground biomass, incidence of rare species, forest utility, land-use and internal control for coffee production. The opportunities to the mobile system are: the ability to collect large amounts and different types of data for little effort/cost while using one system, the system can be learned by users of varying technical experience, and the potential for aligning the economic interests in using the system to automate internal control with conservation goals. The greatest barrier is a lack of supporting organizational infrastructure for database management and support. For this mobile system to be realized in the region there must be significant investment in developing the back-end of the mobile system (database management & analysis) and continuous technical support and training for the community volunteers. We suggest that Pronatura Sur is best suited for this role since they have already invested significant effort into developing community based natural resource monitoring programs in the region.

Press Release

"CLP Graduate Students Use Android Phones and Community Volunteers to Collect Data on Ecosystem Services in the Sierra Madre of Chiapas, Mexico"

For our thesis work in the cloud forests of the Sierra Madre of Chiapas, Mexico, we tested a novel natural resource monitoring methodology that uses Android phones donated from Google.org, mobile data collection freeware (Open Data Kit), and Google Earth as a tool to collect, analyze and share environmental data. In collaboration with the coffee cooperative Comon Yaj Noptic and a private coffee farm and reserve Finca Arroyo Negro, we carried out 190 sampling events with four community volunteer monitors between September and December 2011. We sampled key environmental targets such as avian biodiversity, above ground biomass, forest utility, rare species observations and internal control of coffee operations. These data, collected in digital format with the aid of smart phones, led to the creation of in depth spreadsheets and real time dynamic maps for use on Google Earth. Natural resources information that can be shared and visualized is considered valuable, if not central, to large-scale payment for ecosystem services programs like carbon payment initiatives and the UN REDD program, that will require ecosystem service accounting on a national scale.

Mobile data collection is becoming a prominent tool to support bottom-up data collection around the globe. Mobile devices have been used to report crop yields in Tanzania, conduct household health surveys in Ghana, map near real time disaster needs in Haiti and Japan and project environmental consequences of the recent Gulf of Mexico oil spill. Android features, like predictive text, language options, and built in audio, GPS and images allow for a powerful and diverse data collection experience. Our pilot project suggests that mobile data collection tools have promise to monitor natural resources and contribute to improved environmental governance. These systems are designed to turn the data collection process of traditional top-down conservation on its head. Instead of requiring expert consultants, communities can monitor their own resources and in turn, diversify their environmental awareness. With this system, community members capture environmental data, like evidence of an endangered species, share it within the community and then report it to conservation agencies, empowering agency in a partnership NGOs or governments who can improve their environmental decision making through the use of community collected data.

By giving communities the role of monitoring forest data, regional to international scale payment for ecosystem services programs have the potential to become more streamlined, transparent and accountable. When communities have a tool that allows them to collect, store and validate data concerning their own natural resources, they can take the first step to engaging in improved environmental decision-making. Communities that practice good forest stewardship create benefits across scales: the community gains improved livelihood from their reliance with well-managed natural resources, for NGOs and governments who seek to preserve integrity of landscapes dominated by humans and from an ecosystem services perspective the enhancement of services that flow downstream to other communities.

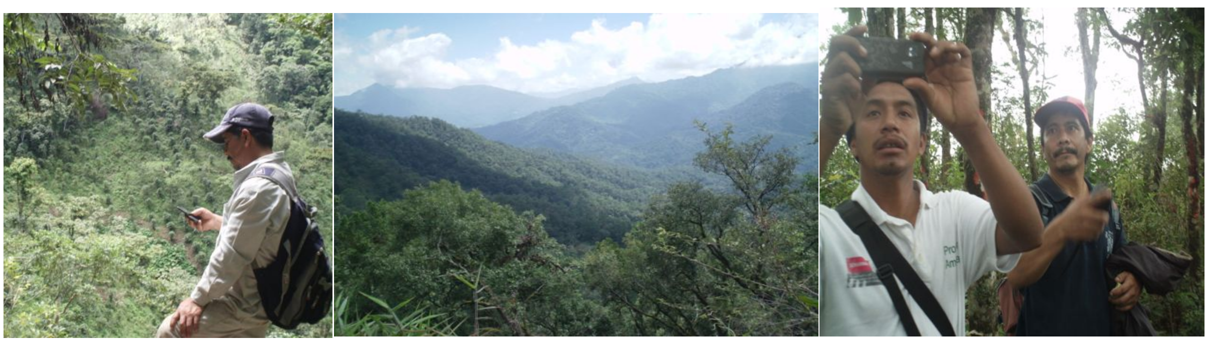

Figure 1 Left, A community volunteer records data in a coffee parcel. Center, Mountains of the Sierra Madre. Right, A community volunteer uses Android phone to take a photo of monitoring target.

CHAPTER 1: Synergistic Problem Statement and Systems Perspective

Integrated Problem Statement

At the heart of large-scale conservation initiatives is the need for accurate and consistent monitoring of natural resources where data collection is historically or currently non-existent. (Daily et al. 2009; Kremen et al. 1994; Lovett et al. 2007). Payment for ecosystem services (PES) initiatives, emerging policy frameworks that propose to pay land owners for the ecosystem services they safeguard, are being heralded as a promising large scale conservation tool by groups like the United Nations Reducing Emissions from Deforestation and Forest Degradation program (REDD+), regional or national water funds, and carbon financiers. Currently, proponents of a PES approach posit that paying for services will result in conservation gains, but have yet to define standards of monitoring, reporting, and verifying the provision of ecosystem services once a payment scheme has been developed. To achieve conservation through a PES requires the daunting task of large-scale natural resource monitoring and accounting: a challenge that is only beginning to be addressed.

The REDD+ program is an example of a large-scale PES conservation initiative that is now beginning to define how it will monitor the success of its implementation. REDD+ intends to reduce deforestation and protect ecosystem services in developing countries by providing economic support to forest stewards who can verify a reduction in emissions through enhancement of carbon stocks (Parker *et al*., 2008). However, there is widespread uncertainty about the ability of REDD+ payments to meet all of its intended targets, especially agricultural small holders in developing countries (Angelsen & Wertz-Kanounnikoff, 2008). If REDD+ is to effectively, efficiently, and equally support small-scale producers without unintentionally supporting continued degrading land-use change, the program design will have to overcome many barriers like reliable verification schemes, land tenure uncertainty, and the transaction costs of dealing with many individual landowners (Campbell 2009). Additionally, the emergence of REDD+ as a global environmental policy has been met with significant criticism and, in some cases, outright rejection by key actors like indigenous organizations (CONAIE 2011; Olander *et al*. 2009; Pattanayak *et al*. 2010). Concerns over market forces, indigenous rights, land ownership, and enforcement have created a highly politicized discourse regarding payments for forest conservation. The discourse aside, REDD+ represents a strong top-down approach to conservation, where nations will develop protocols and payment schemes that will in turn have direct effects for the local level. Presently, the conservation goals of the REDD+ program are often unable to be separated from its volatile policy context (Phelps, Webb & Agrawal, 2010). Many of these barriers can be summed up as the challenges of creating a national Measuring Reporting and Verification (MRV) system where forest resources are reliably monitored and submitted for verification by an independent third party. While MRV is an official term that describes how nations, under the UN REDD+ framework, will assess the enhancement of carbon stocks, it is also a term that applies to any PES initiative that proposes to verify ecosystem service provisioning. An MRV system is simple to conceptualize in a state-run protected area with clear land ownership rights and forest inventories, but this image belies the reality of a country like Mexico, where 80% of forested lands is communally owned (Valencia-Sandoval *et al*. 2010). Furthermore, a strong national REDD+ policy threatens to change the traditionally de-centralized environmental governance (communally owned lands and indigenous reserves) regimes of Mexico, perhaps undoing a strong conservation infrastructure of intrinsic forest stewards (Phelps Webb & Agrawal, 2010). In response to these concerns, many leaders of the REDD+ initiative agree, there is an urgent need to develop an MRV system that is community driven, but also reliable in reporting change in tropical deforestation (Palmer Fry, 2011).

Proponents of community based natural resource monitoring (CBNRM) suggest that communities can play a role to monitor ecosystem services as well as empower effective bottom-up natural resource management (Bonney *et al*. 2009; Danielsen *et al*. 2007). When participatory approaches are used to monitor natural resources, these programs can result in significantly more conservation management interventions compared to conventional scientific methods and are carried out with lower costs (Danielsen *et al*. 2005). Additionally, land use comparisons between community managed lands and protected areas suggests that deforestation rates are higher in protected areas than in community managed forests suggesting that community involvement may be a more successful conservation strategy than top down protected area creation (Porter-Bolland *et al*. 2011). Despite the proposed benefits to this approach, there is uncertainty in the types of data that can be collected, their accuracy, and most importantly whether participatory approaches significantly improve rural livelihoods. Therefore, there is a research need to identify what types of monitoring methodologies are feasible, suitable and significant to PES frameworks (Danielsen *et al*. 2010, 88-112)

Mobile solutions for health and environmental challenges are growing rapidly within the development sector. The open-source platform for sharing near-real time crowdsourced information like Ushadidi.org demonstrates some of the complex challenges being tackled using mobile systems: improving the response time to natural disasters, gathering and disseminating crucial health information to rural areas, tracking human-wildlife conflicts and monitoring critical natural resources to report illegal extraction (Banks & Burge, 2004). A survey of 560 non-governmental organizations (NGO's) revealed that 67 percent of them report one of the key benefits to using mobile technology is the ability to gather and transmit data more quickly, while 91 percent report the ability to reach audiences that were previously difficult to reach as a tremendous advantage (Kinkade & Verclas, 2008). While mobile solutions hold promise to improving the accesses, flow and validity of information, conditions that are vital to implementing community based monitoring programs, there is a growing need to research what are the social impacts and conditions needed for scaling up mobile pilots to regional and national levels (Chetley, 2006).

Google.org, the philanthropic arm of the search engine, recently launched an initiative to address the MRV challenges that large-scale forest monitoring initiatives face at the UN Conference of Parties 16 in Cancún from a mobile perspective. Google.org proposes to use its cloud computing power and visualization software to create forest-monitoring tools in three parts. Google Earth Engine is a computing tool that gives new access to petabytes of remote sensing MODIS and LANDSAT imagery and uses cloud computing to allow individuals to run calculations at previously restrictive scales (Rebecca Moore, 2010). Google Fusion Tables is an online database program that allows for simple upload download, sharing and viewing of data with built in features for merging datasets, data privacy and applying formulas to values like allometric equations. Finally, Google's mobile arm, Android, is incubating a program called Open Data Kit (ODK), a freeware program that allows users to build digital data collection forms and have users remotely upload in-situ point-referenced data to Google Fusion Tables and other online database applications (Hartung *et al*. 2010). Because of its implications, Google.org has presented ODK as a tool to be used for bottom-up natural resource management. Google.org proposes that these three tools, for analysis, storage and data collection, can facilitate large scale MRV, especially in the context of REDD+.

The aim of our project was to assess the potential of mobile-based community monitoring as a means to address the challenge of creating a comprehensive natural resource monitoring and accounting system. We set out to construct and carry out a system for community forest monitoring that uses Google's proposed monitoring framework to collect natural resource data with community volunteers. Through a social analysis, we assessed learning curves and monitor perceptions of the system to add to the growing body of knowledge of mobile data collection for conservation. Our thesis work, in collaboration with local conservation actors, agencies and communities uses a pilot study approach to analyze the ecological, technical and social barriers and opportunities for mobile community monitoring in the Sierra Madre of Chiapas.

Human – Ecosystem Context

The Sierra Madre of Chiapas is a 280-kilometer mountain chain stretching along the coastal plain of the state of Chiapas in Southern Mexico (Reference Encyclopedia) (Figure 2). The region is known for its astonishing biodiversity, referred to as a Pleistocene Refuge, as many of the plant and animal species found in the region are rare and endemic because they survived the climatic changes of the ice age (Morrone, 2010). Between its evergreen tropical and pine-oak cloud forests the mountain range plays a critical role in water catchment services for its 27,000 habitants in the surrounding area and urban areas like Chiapas capital, Tuxtla Gutierrez (Zepeda & Rodriguez, 2010). There are 1.2 million hectares of protected areas spanning the Sierra Madre, including the popular tourist destinations of El Triunfo UNESCO Biosphere Reserve (Reserva Ecológico Biosfera El Triunfo REBITRI) and La Sepultura (The Nature Conservancy, 2012). IUCN and Bird Life International consider the regions protected areas to be top "Important Bird Areas" as they are habitat for over 200 migratory bird species and contain threatened species such as the Quetzal (*Pharomachrus mocinno*) and the Exotic Horned Guan (*Oreophasis derbianus* (UNESCO, 2007). Aside from the high rates of biodiversity the region also provides Mexico with 43.4% of its hydropower, about 13% of the countries overall energy, making it a high priority for protection due to its hydrological services provision (INIFAP, 2011 & Santoyo-Castelazo *et al.,* 2011).

Figure 2 Red circle indicated by gold arrow designates the Sierra Madre of Chiapas, Mexico (Map created using ArcExplorer)

There are a variety of socioeconomic issues in the region that are threatening the protection of its biodiversity and hydrological services. The flow of immigration from Guatemala to Mexico has been consistently growing since the Guatemalan civil war (1960's – 1990's) but in the past decade this trend has dramatically increased due to the drug related violence on the Mexican-Guatemalan border (Smith 2006). The influx of Guatemalan migrant workers during the coffee harvest season in addition to the refugees is increasing the population pressure on natural resources in the region. In addition to population pressure the protected areas struggle to enforce against illegal harvesting of non-timber forest products, like medicinal plants, and the hunting of endangered species (UNESCO, 2007). Lastly, climate change has been predicted to reduce the amount of viable farmland available for the primary economic activity in the region, coffee production. The changing climate in unison with the socioeconomic pressures is creating a pattern of land use change from traditional and resilient agroforesty systems (like shade-grown coffee) to more vulnerable mono-crop systems (Lin *et al*. 2008 & Vandermeer *et al*. 2009).

In response to these environmental and socioeconomic pressures the Sierra Madre of Chiapas has been indicated by researchers as having technical and social feasibility for sequestering carbon within the agroforestry/forestry sectors like shade-grown coffee, silvopasture, and traditional mixed milpas (De Jong *et al*. 1995). Furthermore, Harvey, Dickson and Kormos (2010) state that optimal REDD+ policy design that can incorporate the dual benefits of mitigation and biodiversity conservation are geographic locations with high biodiversity and low opportunity costs for switching to practices that satisfy REDD+ payments. The Sierra Madre, with its current shade-grown coffee infrastructure and high biodiversity presents a prime location to capitalize on both the mitigation (continuing to support shade-grown coffee conservation practices) and biodiversity conservation benefits.

Recently, Ambio, Conservation International, Pronatura Sur, and the Mexican Comisión Nacional de Áreas Naturales Protegidas (CONANP) carried out six pilot carbon-monitoring projects in the Sierra Madre of Chiapas. The pilots measured carbon using semi-quantitative and quantitative methodology developed by the Mexican Carbon Program. The quantitative sampling methodology involved measuring all pools of carbon (above and below ground biomass, litter, dead wood and soil) for a complete analysis in order to form regional baselines. The semi-quantitative methodology used the Bitterlich or fixed angle method to estimate above ground biomass only (Grosenbaugh, 1952). The goals of the pilots were to assess the accuracy of the semi-quantitative method in hopes of its use as standard biomass estimation. These pilots demonstrate the preparation of the region for PES programs as another tool to protect the regions agriculture productivity, livelihoods and ecosystem service provisioning.

Literature Review

Climate change and Agroforestry Systems

There are two fundamentally separate approaches to combating climate change from deforestation: adaptation and mitigation. Mitigation addresses the causes of climate change such as reducing the sources of greenhouse gas emissions while adaptation addresses the impacts of climate change in order to build resilience (Locatelli *et al*. 2011). A key area of opportunity for reducing the effects of climate change is strengthening agroforestry systems that are indicated to provide both adaptation and mitigation outcomes (Guariguata *et al*. 2008). These systems combine productive agricultural activities as well as forest reserves or inter-mixed woody species that sequester carbon (mitigation) and reduce risk from climatic events (adaptation). Focusing on strengthening agroforestry systems may be a 'win-win' policy strategy in addressing climate change, but few large-scale climate change policies have incorporated the advantages of this overlap and instead have focused on independent approaches (Locatelli *et al*. 2011). In the tropics, effective combined mitigation and adaptation strategies are urgently needed.

REDD+ and Community Monitor, Report and Verify Systems

To understand the policy background between REDD+ and community monitoring we participated in a workshop commissioned by the World Bank´s Forest Carbon Partnership Facility and organized by the Centro de Investigaciones en Geografía Ambiental of the Universidad Nacional Autónoma de México (CIGA-UNAM) entitled “Linking Community Monitoring with MRV in REDD+”. The key concepts that emerged from the final workshop report and input papers were highly applicable to contextualizing our pilot project with up to date research and highlighting areas of greatest need of study (CIGA UNAM, 2011). The following is a summary of the main themes that were discussed and the individuals who presented or identified these concepts.

The workshop was created in part to form consensus about how community monitoring might be included in REDD+ considering that the Body for Scientific and Technological Advice of the United Nations Framework Convention on Climate Change is currently developing policy that sets standards for MRV in the REDD+ context. The overall consensus among the workshop participants was that if community monitoring is to be included in national REDD+ policy, it must both support the larger MRV effort while at the same time delivering benefits that are of local value (CIGA UNAM, 2011). Many participants, including the Senior Ecologist for the Nordic Agency for Development and Ecology, Finn Danielsen, presented evidence for the additional benefits of community monitoring. These additional benefits include linking the national REDD+ program to local decision making, mitigating alienation of carbon stocks with local communities, promoting transparency and accountability, reducing the risk for REDD+ to undermine local forest control, improving the sustainable use of forests and contribute to equitable benefit sharing (CIGA-UNAM, 2011). Currently, it was noted, that the REDD+ program maintains a uni-directional data flow from technicians in the field to national databases. This model provides little incentive for monitors to carry out sampling of REDD+ targets. Therefore, community monitoring should include a system where processed data is made available to communities to promote transparency and accountability (CIGA-UNAM, 2011). Thus, the overarching theme of the workshop was that community monitoring should form a core part of MRV for REDD+, but the challenge ahead is to address barriers and identify standard methodologies.

The key barriers identified to successful community monitoring program were:

- Monitoring targets standardized at the national level under REDD+ may not have local relevance
- Data collected by monitors may not be reliable
- The infrastructure for near real time monitoring of carbon stocks does not exist in certain areas
- Without funding, there is no current motivation for monitoring

The key recommendations of the workshop for further action steps were:

- Encourage national policy to develop community based MRV protocols
- Pilot test community monitoring programs that monitor and report REDD+ indicators to test effectiveness and provide evidence to doubters
- Search for mutual relevance in monitoring targets between the community and national REDD+ program
- Conduct more research to understand the additional benefits of community monitoring

At this stage, actual REDD+ projects have been either “readiness activities” or “REDD demonstrations” because no international REDD policy is currently active (Wertz-Kanounnikoff & Kongphan-apirak 2009). Therefore, case studies that demonstrate how REDD+ interacts with communities are only just emerging and do not provide direct comparisons. However, a review of community based monitoring of REDD+ elements does help illuminate potential opportunities and barriers for using community driven monitoring schemes (Table 2).

Table 2 Larrázabal y Skutch 2011 Review of Community monitoring for REDD Variables

Monitoring activities carried out	Case study	Country	Forest Type
Biomass survey for assessing carbon stock following the IPCC (2003) Good Practice Guidelines.	B. S. Karky & Skutsch (2010)	Nepal	• Sub-tropical broad leaved • Lower temperate broaded leaved • Temperate conifer.
An overview of participatory biomass and carbon estimation. Application of methodologies of national inventory, IPCC, McDicken and literature to execute inventory and calculate the biomass and carbon density	R. Shrestha(2011)	Nepal	• Lower temperate broad-leaved forest • Pine forest
Comparison of carbon stock changes in four villages	Zahabu & Malimbwi(2011)	Tanzania	• Woodland, • Lowland • Montane forest
Cutting-edge technology model for measuring and monitoring forest carbon emissions.	Bey(2009)	igeria	• Lowland • Hill tropical forest
First approach to an experience on carbon stocks measurement using cyber tracker in Michoacán state.	Peters-Guarin& McCall (2010)	Mexico	• Temperate forest
Measuring carbon loss from forest degradation.	Danielsen et al. (2011)	India	• Temperate forest
		Madagascar	• Dry forest
		Tanzania	• Miombo woodland
Reforestation activities	Leimona et al. (2006)	Indonesia	• Grassland Dry farmland
To record the carbon outcomes of typical community forest management regimes Assess local communities' capability of making carbon stock measurements themselves.	M. Skutsch& L. Ba. (2010)	Guinea Bissau Mali Senegal	• DryForest

The eight case studies in Table two demonstrate and assess the potential for communities to measure REDD+ variables like carbon stocks, tenure boundaries, reforestation activities and detect leakage elements. The conclusion from these case studies was that communities were capable in collecting accurate data as long as some technical training was involved (Larrazábal & Skutsch, 2011).

As a proxy, experts are using lessons learned from 20 years of integrated conservation development projects to form best practices for community engagement in the REDD+ context (Blom *et al*. 2010). Thus best practices with community monitoring implications are having measurable and clearly defined goals, design projects to be adaptable and flexible, involve the communities in all phases of the project and markets must be available for communities' products and services (Blom *et al*. 2010). Within these goals, community monitoring has been indicated to measure goals of REDD initiatives in terms of leakage and benefit sharing, can strengthen local markets and carry out the actual account of carbon stocks. It particularly stressed that community involvement can help to monitor safeguards, like equal benefit sharing, that may be lost in top down approaches.

Expert Feedback for Community Monitoring Case Studies

The workshop in Mexico City also allowed us to interact with international and regional experts in order to gather feedback for our project approach. Elsa Esquivel, Specialist of the Environment and Integrated Development, of AMBIO, Mexico noted that in order for these community monitoring projects to be sustainable there must be consistent support from local NGO's (CIGA UNAM 2011). Our project will add to the number of studies on community monitoring and intends to build capacity with Pronatura Sur to implement the use of the mobile technology for community monitoring projects in other parts of Chiapas.

Israel Amezcua Torrijos the Regional Coordinator of the Zoque Jungle for Pronatura Sur, emphasized the need to build capacity within communities for visualizing their data in a format suitable for the national level. Additionally, he mentioned the need for communities to be trained on how to selectively choose which data to share with the national level, or how to manage their own point-referenced data sensitively. From this feedback we planned to explore and present the data security capability of our pilot system.

Mandar Trivedi, Head of Science for the Global Canopy Program, commented that a pilot program in coffee production systems is valuable because shade-grown coffee is a viable production practice for ensuring the REDD+ safeguards of biodiversity and livelihood protection. Monitoring of resources within a productive system could represent an area of mutual relevance of monitoring targets (CIGA-UNAM, 2011). Our pilot project aims to build capacity for members of a community that relies on shade-grown coffee production, which indicates the potential for long-term sustainability if a carbon credit system were to arrive.

Patrick Durst, the United Nations REDD Program Country Director to Vietnam, presented about the need to present the results of all community data collection back to the community in order to build trust and facilitate communication from all the actors involved (CIGA-UNAM, 2011)

Finally, Tanya Birch, from Google Earth Outreach, presented about the use of Google tools to carry out a mobile-based community forest monitoring system. The case study she presented was the Suruí tribe in Brazil, who has pioneered the use of this system to prepare their forested lands for carbon financiers. She expressed the desire for more pilot studies, as the technology is in need of field testing for improved development.

Mobile Monitoring Technology

Groups, like Mobile Active, have proposed that with five billion mobile phone subscribers worldwide the area of mobile data collection is a significantly underused yet beneficial tool within the NGO sector. In our project we are testing the feasibility of mobile phone technology, Android devices programmed with ODK data collection software, to communally monitor forest resources. This pilot project has the potential to add to the growing body of knowledge on mobile data collection. Additionally, field testing has shown that the mobile data collection process is actually 20-30% faster in the field and the statistical analysis takes hours instead of weeks (Muammar, 2011) indicating that this mobile technology can address many of the efficiency and near-real-time data needs of community based monitoring projects within the REDD+ framework.

In one mobile-based ecological application, Peters (2011) used a smart phone application called Cybertracker to carry out community mapping of forest carbon services in Mexico. The community monitors mapped firebreaks that were a required management of a regional PES program (Peters-Guarin, 2011). It was noted that the use of mobile phones for data collection as an innovative way to bridge the younger and older generations within a community (Peters-Guarin, 2011). Since the younger generation is more likely to be technologically literate while the older is more likely to have traditional ecological knowledge of the area, teaming the two together to monitor their resources is a way to facilitate interaction and ownership of the younger generation in their community and their resources. While our pilot project will not directly investigate this subject it will be an interesting platform for which future studies can address. However, there are some important considerations to make before using mobile phone technology to collect data in the field. Currently, the cost of the phones we are intending to use for our project ($130 USD) may be too expensive for communities to purchase of their own accord. Therefore external funding may be needed to start these projects along with expert advice and guidance on how to use the technology. In a case study among 23 forested communities in Tanzania, forest use fees and fines provide the entire funds for park guards to carry out surveillance monitoring (Topp-Jørgensen *et al*. 2005). In these communities, the motivation for data ownership helped create a mechanism for a self funded monitoring scheme. These human, social and financial capital investments will need to be considered when developing a sustainable community forest resource mobile monitoring tool.

Current ODK Use in Practice

While Open Data Kit (ODK) is a new web tool, it has already been used in many applications. Several articles and case studies on the use of ODK in the developing world highlight some of the difficulties to implementing this technology, which will provide good guidance for our trainings and the development of the mobile system. A case study using ODK for health surveys in rural households in Mali suggested that users immediately send or upload data for inspection to help reduce the chance of error or irregularity repeatedly occurring in a form (Jeffrey-Coker, Basinger, & Modi, 2010). Due to the irregularity of cell phone service in rural areas of developing countries they used a program called Kobo postprocessor, which is an offline tool for data syncing. This will most likely be the condition we will find in the field so it will be useful to utilize all available offline tools to immediately upload the data and inspect it for errors. Finally, a training manual developed by eHealth-Nigeria (2011) highlights the importance of labeling each phone and requiring users to sign a contract so they take ownership over the devices before distributing them. This method to ensure ownership is applicable to our study because we left the phones with the monitors for weeks at a time.

The Nature of Community Collected Data

The goal of ecological monitoring is to establish baseline conditions of the natural and human ecosystem, then develop testable hypotheses in order to understand indicator response to influencing anthropogenic and natural factors (Murphy, 1990). Monitoring is particularly valuable as a tool detecting the effect of conservation management interventions (Kremen *et al*. 1994). Monitoring can be defined as either 'targeted' or surveillance. Targeted monitoring is hypothesis driven and surveillance monitoring is volunteer or opportunistic, often likened to inventory work. Surveillance monitoring, often the dominant type of monitoring by volunteers has the added benefit of detecting unpredicted changes or findings (Wintle *et al*. 2010), but has been criticized as weak in its ability to detect trends and causal mechanisms as well as being less cost-effective than hypothesis based approaches in the long run (Nichols & Williams, 2006).

Concerns about the ability to detect true trends with community monitoring has shed doubt on its ability to succeed as a monitoring strategy due to its reliance on surveillance approaches (Rodríguez, 2003). Nevertheless, Wiersma (2010) suggests that as new technology becomes available and data needs increase, volunteer surveillance monitoring is likely to represent a huge potential for filling data gaps and generating quality science. Additionally, a comparison on community monitoring with expert monitoring in the REDD+ context reveals that while expert monitoring outperforms community monitoring in data quality and management, community monitoring is stronger in many other areas like reduced costs and added value (Table 3 Knowles, 2010, following page).

Therefore, to acquire the proposed benefits of community based ecological monitoring (reduced cost, sustainability, and improved local environmental governance) a flexible, but rigorous approach to methodology and interpretation of results is needed (Danielsen *et al*. 2000). The goal for community based ecological sampling should be to identify or develop methodologies that have scientific rigor, applicability in the REDD+ context and feasibility for local monitors. We have learned that simple, cost effective methodologies exist, and have been analyzed by previous research. For example, disturbance checklists (Holck, 2007) and forest utility surveys (Danielsen *et al*. 2011), are two methods that are cheap, effective and valid in the REDD+ context and have been vetted by peer review. Additionally, we have learned that certain types of monitoring are more applicable in community approaches and are often indicator based like fixed point photography, key species counts, harvest volumes and perceived changes in natural resources (Danielsen *et al*. 2005). When we reviewed traditional sources of forestry methods in forestry handbooks, we found that the academic approaches were very distant from the community approaches (Newton 2007). Nonetheless, some methods handbooks do exist in community settings, if not participatory (Skutsch, 2011; MacDicken, 1997; Walker, 2011).

Table 3 A Comparison of monitoring by external experts and community residents from Knowles 2010

Monitoring Component	External Consultants	Local Community Residents
Cost	High professional fees, travel and accommodation costs	High initial set-up and training costs followed by substantially lower salary, travel, accommodation costs over time
Local knowledge	Usually poor. Local guides and translators usually needed	Good. Residents typically know the area well in terms of access, logistics, local authorities, laws, and species names
Data quality	Good	Good, but dependent on appropriate training and data verification
Consistency	Potentially low if same consultants cannot continue with monitoring over lifespan of project	Potentially high if same team members or at least the same coordinators can be maintained
Intensity	Usually low. Too costly to spend long periods in field	Good. Even if sampling is done part-time, substantial travel and set-up time is saved
Value addition	Low. Usually limited to technical input and PDD compilation	High. Project success depends on local resource users. Monitoring by local creates ownership
Spin-offs	Maybe for consultants' business, not for community	Participation adds to the skills levels and capacity of local residents. Possible spin-off to other community PES activities
Management	Expected to be good	Potential area of concern in many communities
Logistics	Consultants; flight, vehicles and accommodation costs are high. In remote areas, costs escalates when vehicles are needed	If locally organized is cheaper and more appropriate, e.g. working by foots or animal can be effective because field surveys are spread over time
Initial inputs, e.g. time	Low. Assumption is that professional teams need relatively little preparation time	High. Takes more time to identify, train and equip teams
Collection of other important data, e.g. socio economic information	Generally poor. Very challenging to understand local socio-economy and culture, time-consuming to collect the data	Good. Built-in knowledge of local economy and culture; easy to collect initial information and monitor changes

Technology Acceptance Model

The Technology Acceptance Model is a framework used to predict the adoption potential of a new information systems technology by an individual user in the workplace setting (Figure 3, following page). Davis (1989) created and tested the model using the personal variables of *perceived ease of use (E)* and the *perceived usefulness (U)* and measured their influence on the behavioral intentional to use a system. The first is the degree to which an individual thinks learning the new technology will be free of effort and the second is the degree to which an individual thinks the technology will be useful to them. These variables generate the *attitude toward using (A)* that dictates the *behavioral intention to use (BI)* the technology. These last two variables are based on research derived from the field of psychology (Venkatesh, 2003). The culmination of all these variables can be measured by the *actual system use*. Traditionally, these variables are used to define questions that are administered to users in surveys. The results from these surveys are then quantified using statistical analysis and plugged into the model to get numerical value that predicts a users acceptance.

In summary, if an individual thinks learning an new Operating System (OS), like Mac OS, will be easy to learn and help them advance in their career then they are more likely to have a positive "I want to use this information system" attitude and demonstrates this attitude in their behavioral intention to use, "I'm going to sit down and learn this OS" and then the actual use of the system, "I've figured this out and plan to use the Mac OS instead of Windows OS from now on."

Since the inception of this model a significant amount of research has been conducted on various different *external variables* influencing the *U* and *E*. This research has produced numerous iterations of the TAM, creating what some critics call a "state of theoretical chaos and confusion in which it is not clear which version of the many iterations of TAM is the commonly accepted one." (Benbasat & Barki 2007, pp. 211). Indeed, upon review of the literature it is apparent that many models currently exist with which to choose from. For our study we chose to work with a meta-model based on its breadth of coverage of the TAM literature. This meta-model is an attempt by Venkatesh (2000, 2003, 2008) to synthesize and unify the TAM literature into one model called the, Unified Theory of Acceptance and Use of Technology (UTAUT) (Figure 4, following page). However, while criticisms have been brought to this model in that the increase in complexity of variables reduces the predictive power of the model, it demonstrates how complex the interactions are that determine individuals acceptance of a new information technology system. We used this model to help guide us on things to focus on for our qualitative data collection and as a framework to analyze and describe our results.

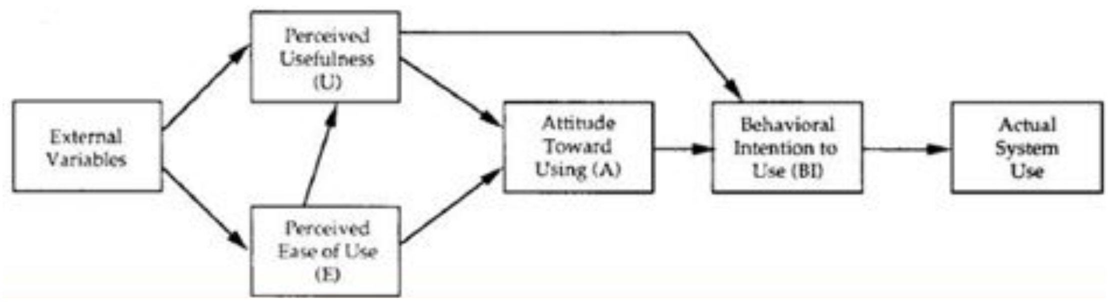

Figure 3. Technology Acceptance Model (Davis 1989)

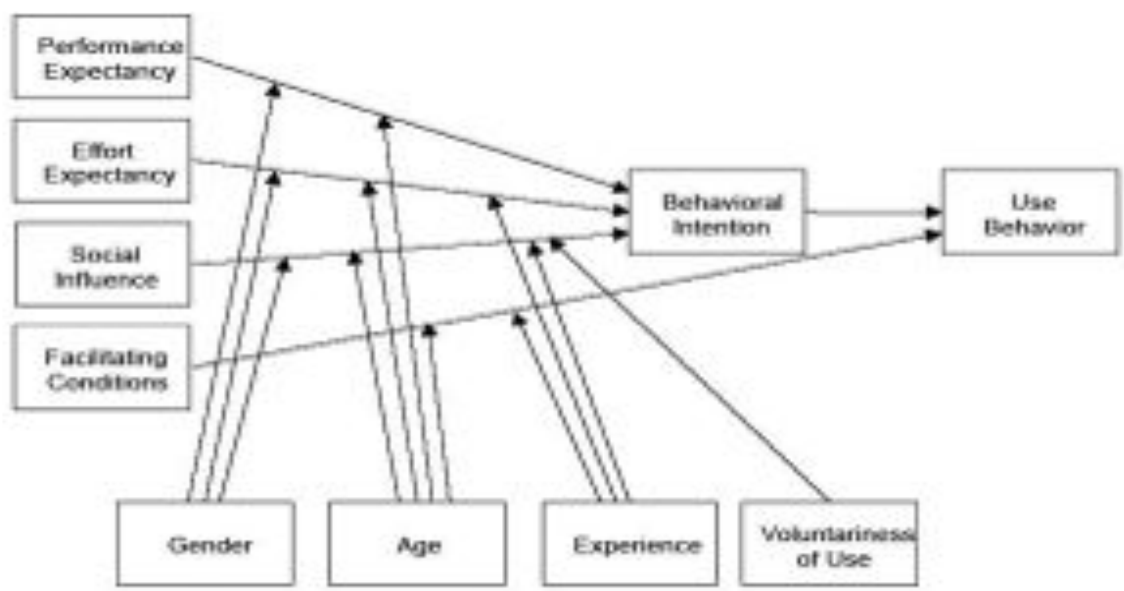

Figure 4. Meta-model of the TAM demonstrating a synthesis of eight different iterations (Venkatesh, 2003)

Stakeholder Description

The stakeholders we engaged with were a combination of software developers, regional conservation actors, coffee cooperatives, private coffee operations and local landowners.

Google Earth Outreach is a branch of Google Earth that provides technical support, knowledge and resources to non-profits and public benefit organizations to help them visualize and share their story using Google Earth and Maps. Google Earth Engine is an environmental platform that utilizes 25 years of satellite imagery in the Google cloud to help scientists, citizens, academics, governments and communities map and analyze forest imagery data. Earth Engine uses a universal platform and a standard set of tools that allows for users to collaborate across organizations to have a greater conservation impact. In 2011, Google.org in collaborations with the Global Canopy Program, created the Community Forest Monitoring Working Group. The working group was created to establish consensus on community monitoring methodologies and lobby the international conservation organizations on the value of community driven ecological monitoring. The next conference to be held the summer of 2012 will serve as a platform for technology and forestry experts to advance the field. We used public resources from the Community Forest Monitoring Working Group to design sampling methodology and for background on the current opportunities and barriers facing mobile community based forest monitoring. Since the Community Forest Monitoring Working Group platform provides a space to upload documents and other resources it will serve as a place for us to share our field-testing experiences with ODK. Because the suite of Google tools for community forest monitoring is under development, Google Earth Outreach supported our pilot study with seven HTC Dream Android phones that are designated for training purposes. In return for the hardware and technical support, our pilot study aims to provide specific and broad level feedback for Google Earth Outreach after extensive use of the system in a field setting.

Open Data Kit (ODK) is an online open-source suite of tools designed to help organizations build, organize and manage data using mobile platform. ODK was originally a sabbatical project led by Gaetano Borriello of University of Washington, but continued developing under the direction of researchers at the University of Washington’s Department of Computer Science and

Engineering department. Google.org incubated the project with initial funds and support. The platform provides free tutorials, software downloads and forum-style tech support to help implement and guide the process of developing a mobile data collection system. We used ODK's program for our mobile data collection and management and solicited technical help from one of its core developers, Yaw Anokwa, and consulted the ODK community forum website for guidance on various steps in the ODK process.

Pronatura Sur is a non-governmental conservation organization that operates at the national and state level in Chiapas, Mexico. In 2006, with support from the Mesoamerican Biological Corridor project, Pronatura initiated a community monitoring program with a focus on the Sierra Madre of Chiapas (Macias & Martínez-Fenández, 2010). The mission of this program is to establish a long-term monitoring network for the conservation and management of high priority habitats for birds. El Triunfo Biosphere Reserve is one of the key habitat areas for migratory birds and also one of the sites for Pronatura's community monitoring network. Pronatura has also invested time in developing conservation easements in the areas surrounding El Triunfo. They helped initiate contact with the avian community monitors that would participate in testing the mobile data collection system. We used their protocol for avian biodiversity point counts as one of our methodologies.

Comon Yaj Noptic, is a coffee cooperative located in the municipality of La Concordia and the community of Nueva Paraíso and manages the coffee production of 148 small holders in the buffer zone of El Triunfo. Seven members of the cooperative participate in the Pronatura avian monitoring program and have received training, compensation and field equipment for their monitoring efforts three times a month. We worked with three avian monitors from Comon Yaj Noptic and tested the use of the mobile data collection system for their internal control assessments.

Finca Arroyo Negro is a 400-hectare private property with 200 hectares in coffee production and 200 hectares under a conservation easement with Pronatura. They maintain a conservation coffee label with Rainforest Alliance and have been previously certified and worked with Conservation International and Starbucks C.A.F.E. practices program. Other than coffee production they are developing an ecotourism program along with hopes for a biological research station. We conducted sampling events on their property testing the technology with their park guard who participates in Pronatura's avian monitoring program.

Pakayal is one out of nine properties making up a conservation easement by Pronatura Sur. The property has seven hectares of shade-grown coffee, pine-oak and cloud forest and a small ranch. The property is also part of a civil association (asociación civil – equivalent to that of a NGO) called "Cafeticultores Comprometidos en la Conservación de los Bosques" which is made up of 10 landowners in the area. This asociación civil was designed with the intention to provide a legal framework to accept payments for conservation practices from conservation programs like the ones promoted by the nearby CocaCola plant (Personal Communication, Pakayal Landowner). We conducted our training for two of the monitors (one being the owner of ranch Pakayal) on this property in and also established three avian bird count transects

Ambio is a cooperative that focuses on generating sustainable rural development through promoting sustainable livelihoods, gender equality and cultural preservation along with the conservation of local environments. They do this through designing and sustaining programs that economically incentivize natural resource management. For 11 years they have been working with pilot carbon sequestration projects in Chiapas, Mexico in a program called Scolel' Te that aims to be the leading source of carbon offsets in the Voluntary Carbon Market and future REDD+ initiatives. We met with employees of Ambio to learn about their experience in using the ODK and Android phones for measuring carbon sequestration. They provided us with an overview of the current methods used by Mexico for carbon measurement, semi-quantative and quantitative, and provided guidance on things to be aware of when working with communities.

Systems Map (Figure 5)

Environmental pressures such as climate change; population increase and land-use change are driving conservation organizations to develop programs to reduce the effects of these pressures on high priority conservation areas like the Sierra Madre. Information technology organizations like Google Earth Engine and Open Data Kit are designing mobile tools that can facilitate conservation efforts that need accurate, efficient and large-scale data to make informative decisions about natural resources. Land use and conservation policies are being developed such as the global United Nations REDD+ program alongside with Regional PES programs that aim to pay communities for stewardship of their natural resources. Shade-grown coffee land practices are sources of adaptation to and mitigation of climate change and can also be considered in payments in ecosystem service schemes. These land use and policies all need accurate, efficient and large scale data collection in order to create baseline levels for measuring ecosystem services and verification of stewardship and health of the indicated services. However these land use and conservation policies also affect the communities, which depend of natural resources in the region of interest, the Sierra Madre. Therefore regional conservation organizations such as Pronatura Sur and Ambio have created pilot programs in the Sierra Madre to monitor communities natural resources in an attempt to help mitigate the affects of land use and conservation policies. These organizations used community based monitoring programs (CBNRM) to collect accurate, efficient and large-scale data for these PES programs. CBNRM have been proven to help improve community environmental governance and therefore ensure that they may control the benefits they could receive from these PES schemes. Our pilot project focused on the circles in red in defining a way to implement these mobile tools into community based monitoring programs.

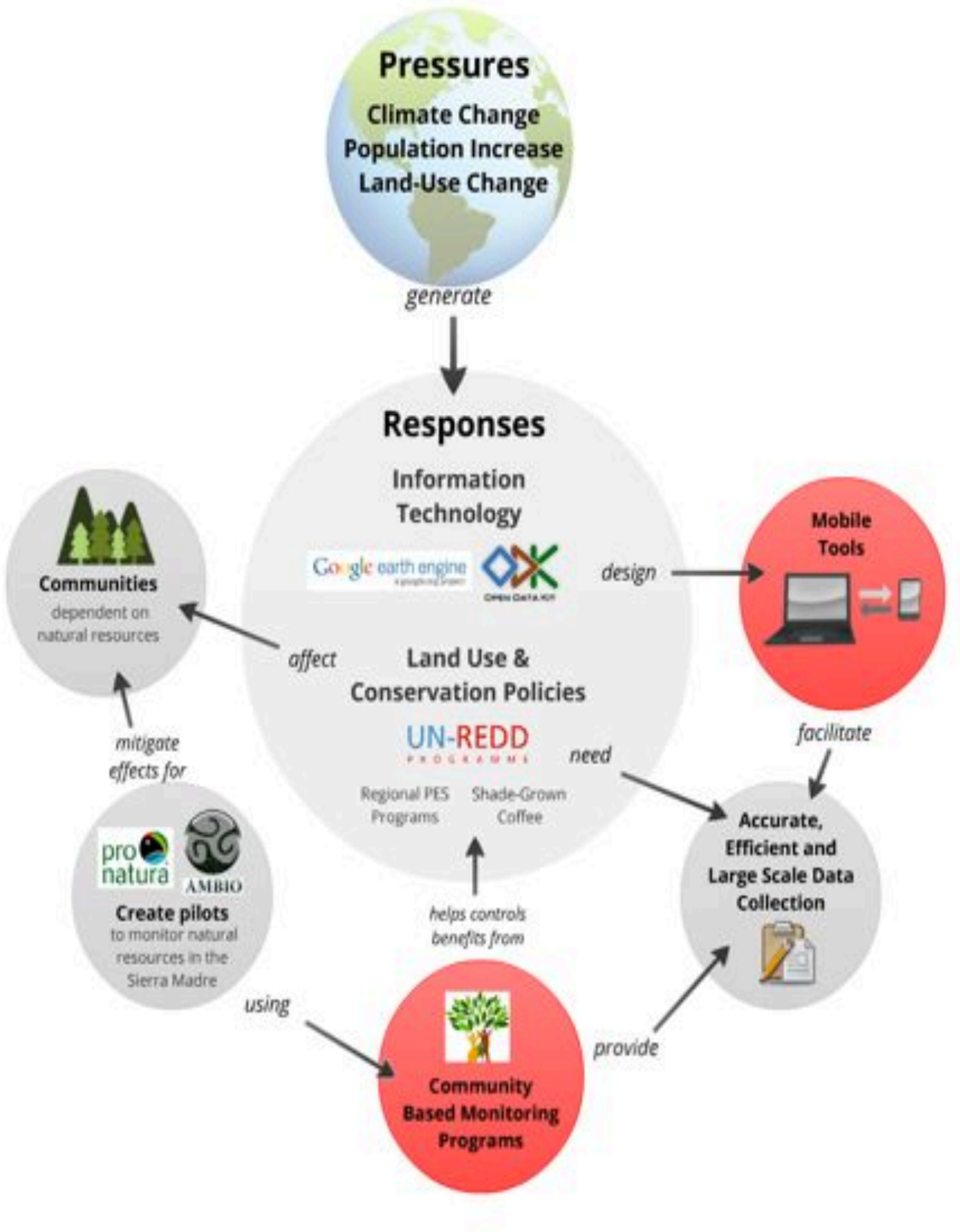

Figure 5 Systems Map demonstrating inputs and outputs that make up a Mobile Community Monitoring System

Project Focus

The following section describes the specific elements addressed by our thesis project.

Need for a Robust Monitor, Report and Verify System (MRV)

In May 2010, Mexico and Norway signed a Memorandum of Understanding that directed $15 million dollars in funds towards creating the "Reinforcing REDD+ Readiness in Mexico" project. This project delineates three main goals; two of which aim to develop, implement and disseminate information on the capacity building for cost-effective and reliable MRV strategies (theredddesk.org, 2011). In response, our project aims to address these goals of implementing and disseminating information on MRV strategies through pilot testing the use of mobile technology as a platform for collecting monitoring data cheaply, efficiently and in real-time. At the end of our pilot project, we hope to comment on key barriers and opportunities for mobile-based community monitoring to fill the data collecting and accounting needs of large-scale PES programs.

Community Based Natural Resource Monitoring in MRV Systems

Community based natural resource monitoring (CBNRM) is a cheap, efficient and reliable way to collect data on important forest resources like those implicated in the REDD+ framework (Danielsen *et al*. 2011). Compared to monitoring conducted by professional scientists, participatory monitoring results in more conservation management interventions (Danielsen *et al*. 2007) at a quicker rate and at equal the cost (Danielsen *et al*. 2005). In addition there are social benefits to CBNRM such as increased environmental awareness of sustainable natural resource management and potential supplemental income to already existing sustainable agroforestry practices (Palmer-Fry, 2011). Considering the qualities of CBNRM such as cost, social benefits, reliability and effectiveness it will be prudent to use this approach in MRV systems within the REDD+ context (Danielsen *et al*. 2011).

Our project intends to test mobile monitoring technology using the concept of community monitoring by training the community members from the coffee co-operative Comon Yaj Noptic (CYN) and employees from privately owned *fincas* in how to use the technology and conduct sampling methodology. Pronatura Sur, in partnership with CYN, conducts a well-established avian monitoring program, which can be a leverage point for adding new monitoring objectives. Our project intends to help build community monitoring capacity into a robust MRV system positioning them to make informed decisions about their natural resources and receive equitable future REDD+ payments.

On the other hand, CBNRM does have potential pitfalls. People are more likely to report positive data than negative data increasing the chances for biased data collection (Campbell 2009). In interviews with members of AMBIO and the Mexican Carbon Project, it was noted that communities are inclined to falsely report conservation activities with the hopes of receiving more financial compensation. Additionally, members of these organizations mentioned that communities might have unrealistic financial expectations causing tension between the NGO's working on the ground, the third-party verifiers and the government officials. We plan for our pilot study to comment on the data quality and motivation concerns of CBNRM.

Relevance within the REDD+ Context

The Community, Climate and Biodiversity standards are voluntary certifications that add value to REDD+ payments by identifying projects that generate net positive social benefits and biodiversity conservation in addition to only reducing emissions (CCBA, 2008). Our project will focus on selecting monitoring targets that satisfy REDD+ and CCBA standards. By linking targets to international standards like CCBA, our project can demonstrate how biodiversity monitoring can be linked into PES programs, creating a possible financial incentive for monitoring. Local actors like Pronatura already conduct biodiversity sampling in the region of El Triunfo Biosphere Reserve. By aligning local monitoring effort with internationally recognized methodologies, data collection in El Triunfo can become both regionally and internationally recognized. Additionally, our project may address some of the political concerns of REDD+. Pro producer groups like Via Campesina, have often rejected REDD+ out of concern over market based solutions and foreign land grabbing. By focusing our project on REDD+ payments for small-scale agricultural operations, we will be supporting a strategy often seen as an area of compromise between staunch REDD+ doubters and proponents alike.

Project Objectives (Figure 6)

Co-generation of monitoring targets – The co-generation of monitoring targets will help the project partners begin to think about community monitoring with regards to what are the monitoring goals and logistical considerations for conducting field sampling. Based on theory of collaborative conservation and REDD+ program best practices, a co-generated monitoring plan is the most appropriate for a project in order to determine targets that have mutual relevance for the all stakeholders.

Field Sampling to Collect Data – Sufficient data needs to be collected in order to test the viability of the methodology and technology. While certain methodologies, like rare species observations, are certainly simple and feasible, for the short term, it is unlikely to collect sufficient data to test its effectiveness. Nevertheless, based on the stakeholder input to monitoring targets, we will carry out a diverse set of methodologies to test how mobile technology interacts with data collection. When sampling, we intend to collect data that is relevant to REDD+ when possible. These targets can be identified by matching with the CCBA's voluntary measurement scheme for identifying social and environmental targets that should receive the "+" in REDD+ (CCBA, 2008). Our sampling methodologies will represent both targeted and surveillance monitoring types with targets like above ground biomass, avian biodiversity and local forest utility.

Incorporate mobile element to facilitate monitoring methodology – Once monitoring targets are determined, we will create Xforms (digital questionnaires accessed by smart phones) that match the monitoring methodology. This is a crucial step in developing a monitoring tool that is flexible and simple to be realistically replicated over a large scale. We plan to design forms with the best design *a priori*, and then adjust them after receiving feedback from monitors in the field.

Visualize data collected using Google Fusion tables and Google Earth – By visualizing data collected in the field, land managers, partner organizations, and local producers can create a quick decision making tool. The adaptable interface of Google Fusion Tables will allow private landowners or partner organizations to analyze data in real time and edit or download data from any computer with Internet connection. Advocates for community forest management suggest that community forest monitoring should serve as the primary mechanism for measuring carbon and actions that mitigate deforestation and degradation in order to put local governance at the center of global PES schemes (Palmer Fry, 2011). To make this bottom-up forest management local producers will need a database and visualization system that can be verified by third parties. We propose that the Google Earth and Fusion Tables have potential to fulfill this role of a community managed MRV system.

Social Evaluation of Mobile Monitoring System – The response of the monitors to the mobile data collection methodology is vital to understand if this pilot project hopes to serve as a model for future mobile community monitoring projects. Evaluating the learning curve will determine the practicality of implementing the mobile components. Looking at the opportunities and barriers in regards to adopting this mobile monitoring technology will help demonstrate where improvements can be made in future iterations.

Present Results back to Comon Yaj Noptic, Arroyo Negro, and Pronatura Sur – We will provide the results of our work in as many forms as possible to the project partners. The minimum goal is to present our final documents to each partner organization. We feel that a person presentation will show the capabilities of mobile-based monitoring as a way to continue informed forest management as well as demonstrate the way forward in using this technology.

Multimedia Documenting the Process – Our methods, using smart phones to capture environmental data and create maps in real time is a new and innovating conservation strategy. We feel that documentation of this process could create valuable public relations materials for Pronatura Sur, Finca Arroyo Negro, and Google Earth Outreach. This multimedia, consisting of a video and an executive summary, could be distributed as a secondary deliverable to interested project partners or relevant organizations.

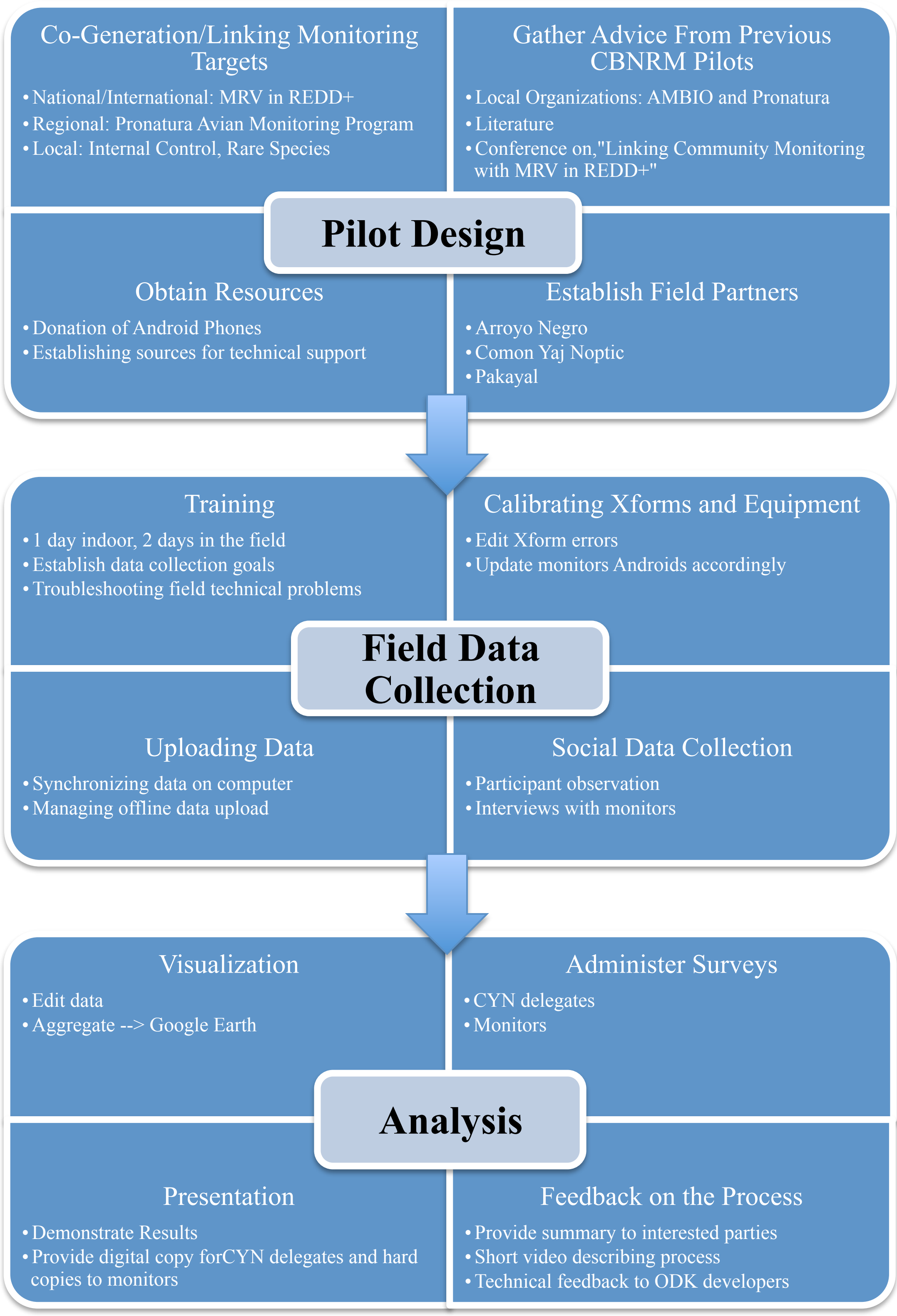

Figure 6 Work flow-chart of our project objectives

CHAPTER 2: Collaborative Methods: Building, Coordinating and Evaluating a Mobile Community Monitoring System

Introduction

The primary goal for our thesis work was to construct and pilot a system for mobile community monitoring that is relevant to our stakeholders' natural resource concerns and then evaluate its potential and barriers. While we worked together closely throughout the project, Adam took the lead on building the mobile monitoring system, which required form creation and modification as well as moving the data from the field to the web based platform to be viewed and analyzed. To do this, he familiarized himself with Open Data Kit data collection system as well as how to view the collected data with Google Earth. Then, he applied this system to pertinent ecological questions in the region, adapting sampling methodology to match form design. Elizabeth analyzed the system from a social perspective. She focused on evaluating the learning curve of the participants and identifying the barriers and opportunities to implementing the mobile system within the greater regional context. To do this, she used a mixed methods approach that included the use of interviews, surveys, field notes and participant observation. She interviewed 10 people including monitors and organizations involved in the monitoring program, and she also collected field notes and participant observation for 21 days in the field during training and data collection. At the end she designed and distributed 26 surveys to get feedback on the barriers and opportunities to the mobile system. The following chapter describes what methods we used to build, carry out and evaluate a mobile monitoring as an emerging conservation strategy.

Site Selection

Training, sampling and presentations were carried out between September and December of 2011 at three main locations in the buffer zone of El Triunfo Biosphere Reserve (Figure 7). All sites were accessed through the municipality of Nuevo Paraíso, Concordia, Chiapas, which is situated in the Cuxtepeques watershed of the Sierra Madre mountains. The Comon Yaj Noptic headquarters is located in Nuevo Paraíso as it represents a central location for much of the coffee productive highlands in the region. We collected sampling at four different sites, Finca Arroyo Negro, Pakayal, Nuevo Paraíso and San Francisco. Finca Arroyo Negro abuts the buffer zone of El Triunfo and is located at an elevation of 1,127 meters with a habitat of pine oak forest, montane could forest and shade grown coffee. Pakayal is located within the buffer zone of El Triunfo at 1,402 meters elevation where data collection was conducted in similar types of habitat, cafetal, pine-oak forest and montane cloud forest. San Francisco is a community of small coffee producers that belong to Comon Yaj Noptic found at an elevation of 1,066 meters. The final site was Ejido Nuevo Paraiso where one monitor collected observational data, located just outside of the town of Nuevo Paraiso.

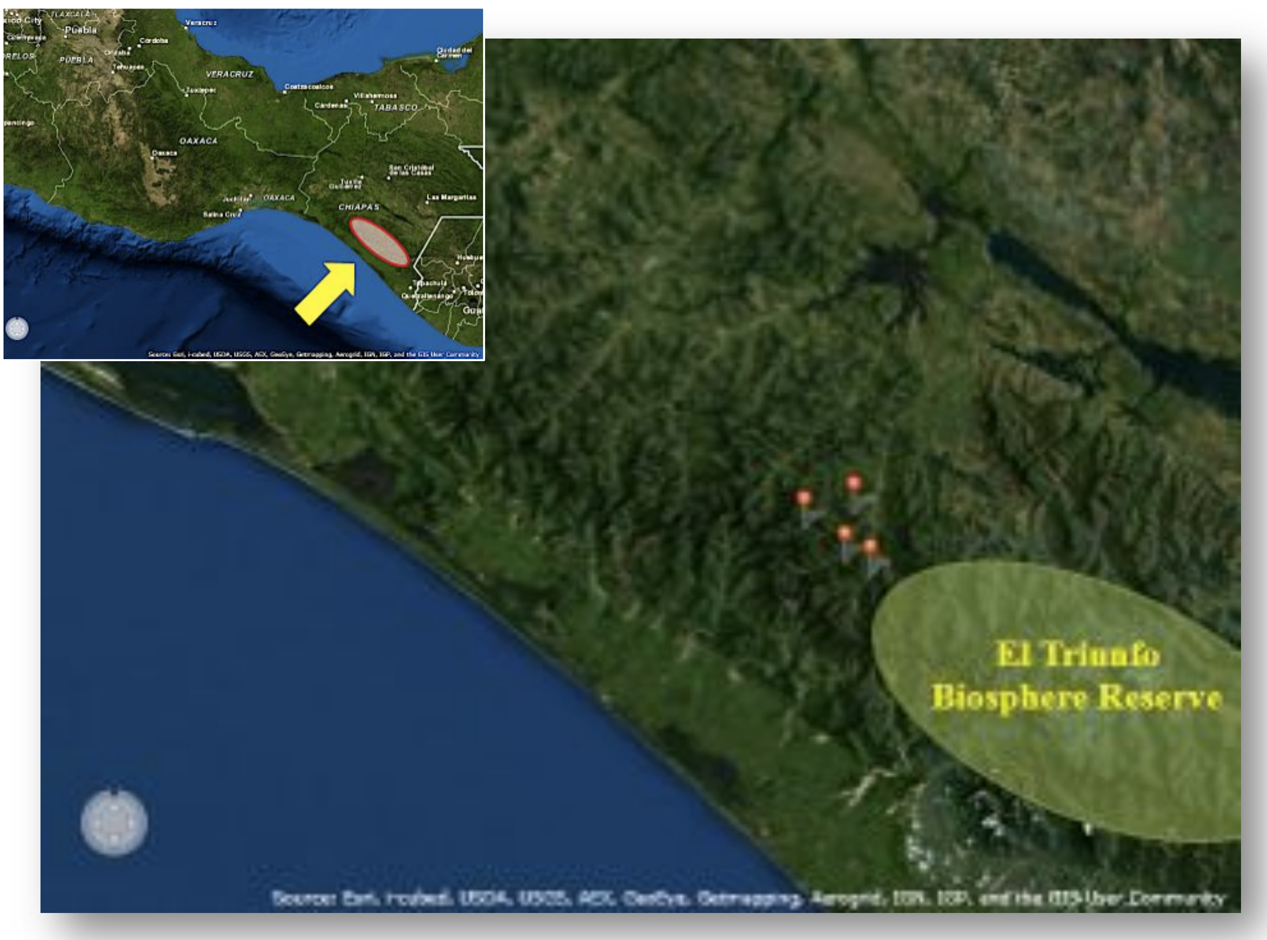

Figure 7 The four data collection sites: Arroyo Negro, Pakayal, San Francisco, Ejido Nuevo Paraiso (Map created using ArcExplorer)

Technical and Ecological Methods: Developing the Mobile System and Ecological Sampling

A mobile-based community monitoring system is a data collection framework where community volunteers or park guards collect ecological data and systematically transform it into usable spreadsheets and maps for analysis. Figure 8 is a flow diagram that demonstrates the design of the mobile monitoring system from the developer and data collector perspective. The figure shows how the web based system is designed to store and transform data and what role the monitors play. The chart is followed by detailed methods description of the process we designed from start to finish.

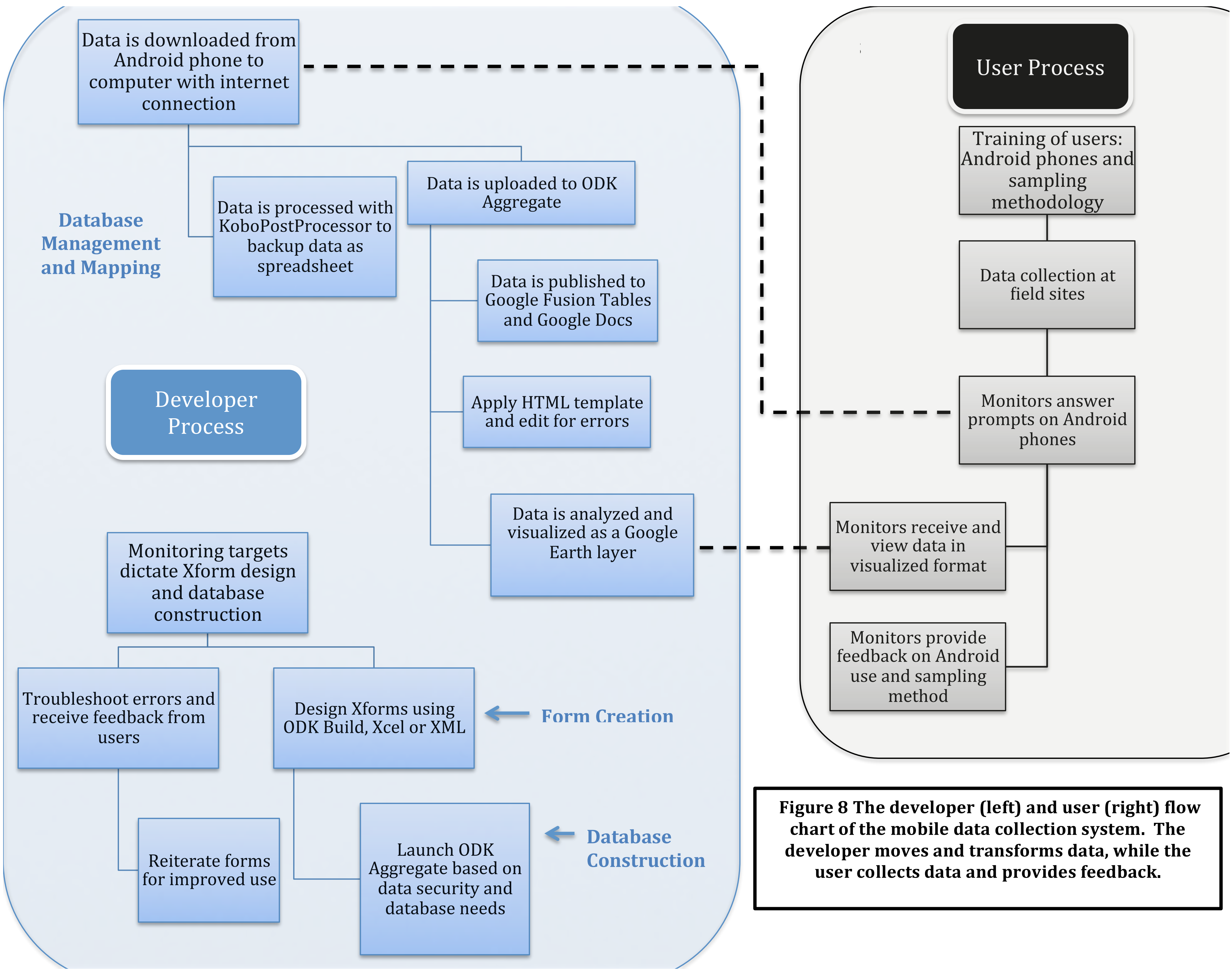

Figure 8 The developer (left) and user (right) flow chart of the mobile data collection system. The developer moves and transforms data, while the user collects data and provides feedback.

Determining Monitoring Targets

The first step in creating a mobile-based community monitoring system was determining relevant monitoring targets. We initially focused on targets that could be useful in a payment for ecosystem services framework. To do this, we examined standards like the CCBA standards for carbon based payment programs (CCBA, 2008). Additionally, we attended a conference titled "Linking Community Monitoring with MRV for REDD+" in Mexico City in September, 2011 where we joined expert discussion on what and how to monitor natural resources relevant to the REDD+ framework. Finally, we interviewed our project partners and stakeholders about what monitoring targets were the most compelling or needed. Based on these inputs we decided on a breadth of monitoring targets that would shed light on barriers and opportunities for a mobile monitoring system.

Developing a Mobile-Based Data Collection System

The primary tool we used for our mobile data collection effort was Open Data Kit, a freeware package of web tools designed to create mobile data solutions (Hartung *et al.* 2011). The initial usage of these tools was in health applications like rapid health surveys and mobile remote diagnosis. Recently, it has been proposed that ODK could be used for community forest monitoring and other environmental verticals. Our goal was to test whether ODK could exist as a flexible environmental monitoring tool, capturing multiple types of environmental data.

We used two ODK tools to help build our monitoring network, ODK Collect and ODK Aggregate. ODK Collect is an Android application that allows users to fill out digital questionnaires complete with the option to capture real time audio, video and images and then send the completed data to an online database. ODK Aggregate is a web application that allows users with a Google Account to store, view and publish data collected from a mobile device installed with ODK Collect. Multiple users with a mobile device using ODK Collect can complete surveys and send the data to the same unique Aggregate website.

ODK Collect uses Xforms, an Extensible Markup Language (XML) format for creating web based forms that follow a question and answer format. Users are prompted with a question that can be answered in multiple formats such as text, integers, select one (or multiple) options and media like audio and images. The user interacts with these forms using the touch screen and keypad of an Android compatible phone (Figure 9 &10, following pages).

Figure 9 The phones were equipped with an internal camera. Here the user is taking a photo of a rare species track.

There are additional benefits to ODK Collect like adding response restraints and hints to guide a user through the process. For example, a user may not be permitted to advance to the following question without answering the current prompt.

When completed, the forms are stored as an .xml file, which can be uploaded to a mobile device and shared to other users. A user of the mobile device will now view the polished digital questionnaire, where they answer the prompts on the screen according to the information they are collecting.

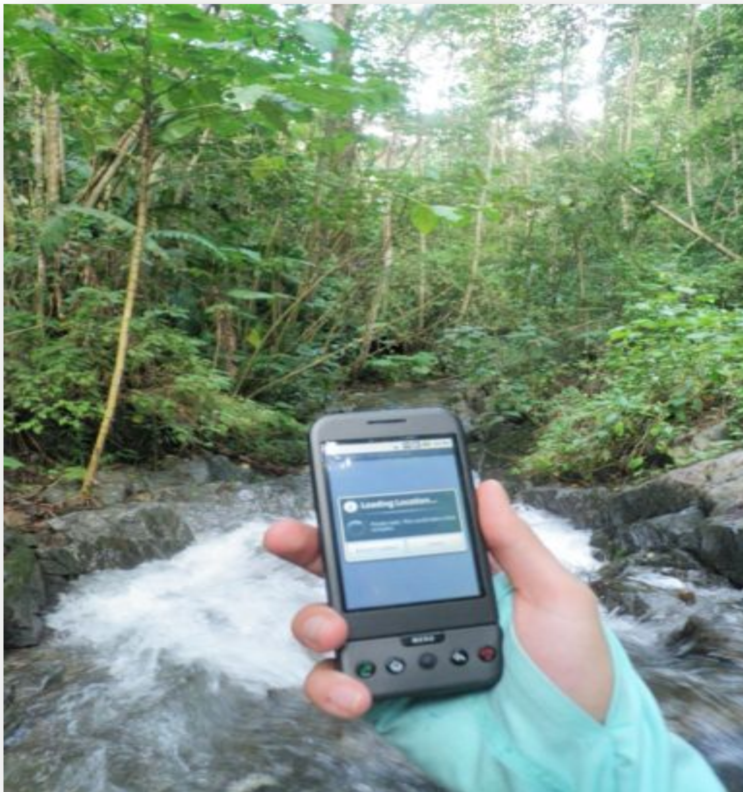

Figure 10 The User is guided through a series of questions. Here, the user collects location data from the phone's internal GPS

Form Creation

After the monitoring targets were determined, we developed a form that corresponded to each monitoring target. These forms were designed to be intuitive as well as dynamic enough to capture all of the data required by each sampling methodology. The first step to creating a form is designing a traditional data sheet that indicates what types of data are required. We used three methods to transform the sampling protocols for each monitoring target into their respective Xform format. The first was ODK Build, a free drag and drop program for designing Xforms. In this system, you design one question at a time by indicating what the user will read and what type of data is to be collected. Then you can drag and drop the questions to develop the order of your form (Figure 11, following page). The second method was another ODK Program called XLS2Xform. In this program you designed an excel spreadsheet with certain formatting restrictions that indicate how the questions will appear to the user. Using a spreadsheet to design Xforms is intended to allow for more flexibility and space for data rich forms (Figure 12, pg. 43).

Finally, we manually edited the XML of forms to correct errors and add desired functionality (Figure 13, following page). With little previous programming experience, we used tutorials and expert advice to develop forms directly in XML. If desired, the Xforms can be created entirely with any of these three methods, but we often used a combination of the spreadsheet method and editing the XML directly. As the forms were used in the field, we took notes on their performance and errors to make subsequent iterations for improved use.

Figure 11 Form creation: ODK Build; The drag and drop menu

	A	B	
1	type	name	caption
2	set form title	Control_Interno	
3	set form id	Control_Interno_1000	
4	get start time	start	
5	get end time	end	
6	get today	today	
7	get device id	deviceid	
8	add date prompt	Fecha	Fecha
9	add location prompt	Coordinates	Ubicacion
10	add decimal prompt	Latitud	Latitud
11	add decimal prompt	Longitud	Longitud
12	add decimal prompt	Altura	Altura
13	add text prompt	Promotor	Ingresa nombre de Promotor
14	add text prompt	Productor	Cual es el nombre de Productor?
15	add text prompt	Comunidad	Comunidad
16	add text prompt	Rancho	Nombre de Rancho
17	add integer prompt	Hectareas_Cafe	Cuantas hectareas de cafe?
18	add select multiple prompt using cafeOptions	Tipos_Cafe	Que tipos de cafe?
19	add integer prompt	Hectareas_Bosque	Cuantas hectareas de bosque?
20	add select one prompt using cultivosoptions1	Otros_cultivos	Hay otros cultivos?
21	add select multiple prompt using cultivosoptiontypes	Tipos_Cultivos	Que tipos de cultivos?
22	add select one prompt using Arroyooptions	Arroyo	Existe Arroyo?
23	add select one prompt using ViveroOptions	Vivero	Existe Vivero?
24	add image prompt	Imagen_Vivero	Tomar foto de Vivero
25	add integer prompt	Vivero_Numero	Cuantas Plantas hay en el Vivero?
26	add select one prompt using cafeOptions	Vivero_Predomina	Que Tipo de cafe predomina el vivero?

Figure 12 XLS2XFORM. Column 1: Programming the style of the question; Column 2: The column heading for the question answers; Column 3: What the user will see on the screen.

```
      <value>6</value>
    </item>
    <item>
      <label ref="jr:itext('/data/DatosdeAves/Punto:option6')"/>
      <value>7</value>
    </item>
    <item>
      <label ref="jr:itext('/data/DatosdeAves/Punto:option7')"/>
      <value>8</value>
    </item>
    <item>
      <label ref="jr:itext('/data/DatosdeAves/Punto:option8')"/>
      <value>9</value>
    </item>
    <item>
      <label ref="jr:itext('/data/DatosdeAves/Punto:option9')"/>
      <value>10</value>
    </item>
    <item>
      <label ref="jr:itext('/data/DatosdeAves/Punto:option10')"/>
      <value>11</value>
    </item>
  </select1>
  <input ref="/data/DatosdeAves/HoraInicioPunto">
    <label ref="jr:itext('/data/DatosdeAves/HoraInicioPunto:label')"/>
    <hint ref="jr:itext('/data/DatosdeAves/HoraInicioPunto:hint')"/>
  </input>
  <select1 ref="/data/DatosdeAves/Especie" appearance="autocomplete">
    <label ref="jr:itext('/data/DatosdeAves/Especie:label')"/>
    <hint ref="jr:itext('/data/DatosdeAves/Especie:hint')"/>
          <item>
            <label>Thicket Tinamou Crypturellus cinnamomeus </label>
            <value>Crypturellus cinnamomeus </value>
          </item>
          <item>
            <label>Plain Chachalaca </label>
            <value>Ortalis vetula </value>
          </item>
          <item>
          <label>Bird3</label>
          <value>Bird4</value>
        </item>
```

Figure 13 Form creation: Editing the XML for the avian Xform

Certain sampling objectives required well-matched form design. For example, Pronatura's avian methodology demanded that users browse through an internal list of over 400 species. This required additional programming of an 'autocomplete' function that works like a search engine. Additionally, Pronatura's transects represented the most ecologically viable sampling unit. Therefore, we added additional questions to the end of the form to maximize the sampling effort. After all of the bird observations were completed, the user was asked to note if any rare species were observed or if there was any evidence of local forest take. Another form building technique that we used was skip logic. Skip logic allows a tree of questions to be developed that are included or excluded based on previous answers. For example, in one method the user is asked if a coffee grower has a nursery on their farm. If the answer is yes, then the program asks a series of nursery questions like the status, number of plants, and dominating species in the nursery. If the answer is no, then the nursery specific questions are skipped (See Appendix I for a list of all form structures).

To create a form to capture sampling for above ground biomass we eventually adapted our form from a preexisting version that employs the Walker et al (2011) methodology for use in tropical Africa. The Community Forest Monitoring Working Group previously provided a link to existing .xml files for free use. To adapt this form, we downloaded it from the web, translated the questions into Spanish and adapted the species and habitat types to the Sierra Madre of Chiapas. To do this, we worked entirely in XML, changing the code of the previous biomass estimation form.

Database Construction

Once the forms are built, ODK Aggregate must be configured to accept completed data collection events for storage. To set up an ODK Aggregate, we first created a unique web identifier for each field partner hosted on Google App Engine. App Engine is a service for web developers to host their applications using Google's storage space in the form of a website. ODK Aggregate then links to the unique identifier through a web link. This website was accessible by password control to only relevant stakeholders. After setting up the database, we customized the interface for each field partner to give password-protected access. Then, each form has to be uploaded to the Aggregate instance that creates a sending (mobile device) and receiving system (web based database) for each Xform used. At the ODK Aggregate website, a partner can view, delete, download and publish data. A larger part of database management was checking for updates and noting errors to the developers of ODK.

Training of Users

Training our field partners was accomplished by one day of mock use session with the Android phones followed by a few days of assisted data collection on actual field sampling trips. The training sessions were conducted one-on-one with a phone for each user and trainer. To begin, we used a sample paper form that asked simple questions like “What is your name?” and “How many people are in the room?” After answering the questions in written form, monitors were presented with the smart phones and given a digital version of the same exact sequence of questions. Additionally, we taught how to use basic functions of the phone like putting to sleep, accessing ODK Collect and charging. We then demonstrated how to save and send data and troubleshoot problems. Finally, we showed where the data was going and how to access it on the web. During our assisted data collection events we practiced all of the different types of monitoring methodology and demonstrated how to remedy errors that we encountered in the field. The assisted data collection events were crucial to our understanding of the system because we were able to observe the experience of a community monitor from many perspectives (Figure 14).

Figure 14 Assisted sampling events for observation and methodology training

Methods for Field Data Collection

Based on multiple inputs we decided on six pertinent monitoring targets that represented a combination of scholarly and stakeholder interests. Pronatura focuses on bird habitat conservation as a central mission and therefore were interested in adapting their avian biodiversity point count method to the Xforms. Through interviews, the monitors expressed a great interest in monitoring rare species. They explained that they spend a lot of time on forest trails, which rare species tend to use as well. The Director of Comon Yaj Noptic was intrigued by the prospect of creating an Xform for their current paper internal control forms because he saw the benefits of a streamlined automated process. Lastly, after speaking with Wayne Walker, lead author of the Woods Hole Research Center biomass estimation field guide, he mentioned that translating the guide into a Spanish Xform would be useful for others community monitoring carbon projects in Latin America. Consultation from the Laboratorio de Análisis de Información Geográfica y Estadística (LAIGE) department at ECOSUR encouraged us to test the ability for the monitors to collect land-use classification data. Finally, a literature review of potential REDD+ indicators revealed that measuring forest utility and rare species observations could link into the larger PES framework. We combined the interests of the various stakeholders and literature review resulting in the following targets: avian biodiversity, rare species, internal control of coffee operations, forest utility, forest cover and above ground biomass.

To measure above ground biomass, we used a methodology from the Woods Hole Research Center that focused on measuring diameter at breast height (DBH) of all trees within 40-meter by 40-meter plots. To establish the center of the plots we used a random number generator to identify a single point along 2.5 km avian point count transects pre-established by Pronatura's avian monitoring program. For sites within the avian monitoring program these transects are created in three different types of habitat: most often coffee, cloud forest and pine oak forest. Selected points that had slopes greater that 35˚ were excluded from the random selection. Once the plot was established, in teams of two or three we measured the DBH of all trees with a DBH greater than 5cm within the plot with a five-meter DBH tape. The trees were identified to species if possible and to functional group of woody tree, palm and liana when identification was not possible. Additionally, we used a sighting clinometer to measure the height of the three tallest trees of each plot. Often, two team members would operate the DBH tape while the third entered the data with ODK Collect. Finally, we used ODK to capture a picture of the four corners of the plot and the plot center for habitat identification and verification of data collection. To estimate above ground biomass, we used the Chave *et al*. (2005) allometric equations for tropical moist forest species and the FAO handbook for estimating tropical biomass (Brown 1997).

Avian biodiversity was measured using Pronatura's sampling protocol (Martínez 2010). Each transect is 2.5 km long with eleven total observation points. Each monitor notes all birds seen or heard at each point for ten minutes and then moves on to the next point until completed. GPS coordinates are recorded for each point as well as habitat type, number of individuals, species of tree the bird is seen on, what strata of vegetation the bird was observed and what type of foraging behavior was observed. Each monitor carries out three sampling events per month at each of the three distinct transect sites located in different habitat types.

To achieve a CCBA standard, a project must demonstrate that is has a monitoring plan in place to measure leakage for five years after any forest activity displacement (CCBA, 2008) Danielsen (2010) demonstrated a method for measuring forest utility (and by proxy potential leakage rates) by community monitors. Based on this methodology we had monitors report the number of cut trees encountered per unit effort of search. Searches were carried out on known hiking routes and roads to provide means of replication. Additionally, we had the avian monitors note the presence of local forest take along the established transects. Forest utility can eventually be interpreted as a rate of number of cut trees encountered per effort search, where effort search is represented as hours walked at a constant rate.

To achieve the CCBA Gold Level standards for biodiversity benefits a project must demonstrate regular occurrence of a globally threatened species (according to the IUCN Red List) at the site. This can include a single record of an Endangered or Critically Endangered individual or the presence of at lease 30 individuals or 10 pairs of a Vulnerable species (CCBA, 2008). Rare species were measured opportunistically when monitors were in the field for other reasons like tending to coffee fields or conducting other monitoring. Opportunistic sampling, or surveillance monitoring, was selected to test the systems ability to capture important species data without conducting rigorous sampling. Rare species sampling often involves time intensive searches or expensive equipment like camera traps or genetic sampling. Surveillance monitoring, while not hypothesis driven, has been shown to make up for inconsistencies of accuracy and rigor with large amounts of data over a fine scale (Wiersma, 2010). To indicate the presence of a rare species, the name of species, the image of the species or evidence and the location was recorded. Monitors also captured rare species information with a separate general observation form.

We created a general observation protocol designed to take advantage of monitors traditional knowledge and time spent on non-standardized sampling bouts. For this methodology, monitors followed a simple form that recorded location, notes, images and audio observations. This form allowed users flexibility to carry out surveillance monitoring for an important target that did not fall into any one category.

The methods for ground verification of land use were developed with Miguel Castillo with LAIGE at ECOSUR. We developed a series of questions that could assist in land use planning and assessment GIS methodology at LAIGE. For this methodology, estimated canopy height, land use classification and a picture facing in the four cardinal directions are recorded. When this data is entered into a GIS it can provide verification to large-scale land use estimations, helping to document land use change. These points were collected opportunistically, with the goal of gathering the largest distribution possible. These land cover assessments could also be used to document additionality or habitats of High Conservation values under the CCBA standards (CCBA, 2008)

Internal control of coffee operations is the maintenance and accounting of coffee operations to prepare for certifications like Rainforest Alliance and Fair Trade as well as monitor productivity. For a cooperative like Comon Yaj Noptic, internal control is the monitoring and reporting of coffee production from about 150 partners, most with one or two hectare plots. To pilot a mobile system for internal control we pulled a representative sample from the Comon Yaj Noptic internal control manual, which is normally filled out by hand by each partner. This manual asks questions concerning a number of coffee production variables like number of hectares in production, hectares in conservation, cultivars of coffee in production and the presence of conservation practices like live fences and protected riparian zones. To test the mobile collection of internal control data, we trained one representative of Comon Yaj Noptic and he conducted assessments at the parcels of a variety of cooperative partners (Figure 15).

Figure 15 Member of Comon Yaj Noptic collecting internal control data on a partner farm

Data Aggregation

Once the above sampling methodologies were carried out, the data are stored on the Android phone's SD card (hard drive). Because we were working in an area of dominantly non-existent phone service or Internet connections, we ruled out the option of having the monitors send data to a database remotely. Instead, we periodically uploaded the data from the mobile units to a laptop computer via USB cable. Then, when the laptop was able to connect to the Internet (either the Comon Yaj Noptic office, Finca Arroyo Negro, or San Cristóbal de las Casas) the data was bulk uploaded to the appropriate database. Once at the database the data can be revised, downloaded, published and deleted.

Data Management, Visualization and Analysis (Google Tools)

Once the data were uploaded to the respective web based aggregates the submissions could be downloaded and published if desired. While the user fills out information in question and answer form, the aggregate converts it into spreadsheet form, readily available for analysis and review. In order to create maps with the information collected, we published the data to Google Fusion Tables with a built in function from ODK Aggregate. Fusion Tables is a spatial spreadsheet program with the goal of creating data rich maps. Once in Fusion Tables we edited the data for completeness and errors in preparation for the data to be mapped. The maps appear as points on a Google map, given the geographic position provided by the user. Google's dynamic maps allow for analysis of each collected point of information and the ability to link to complete data sets, view images and convert to Google Earth format. Having data in Google Earth was our final step. Once there, limited spatial analysis can be carried out like measuring distances and areas. Importantly, these finished maps can be stored, shared and embedded on other websites for data sharing and verification.

A key tenet of data management was navigating the mobile monitoring system and ensuring that collected data was transformed into usable data sheets and dynamic maps. To do this, we designed a methodology for transforming data into its usable state. One tool we used was a program called KoboPostProcessor. This web tool converts completed .xml files (the finished mobile forms) into a single Excel spreadsheet. We used this tool to backup data and conduct analysis for data that exists across sites, like land use and forest utility. The data that are used in the dynamic maps are stored in two places. The majority is within Google Docs, which allows for sharing, editing and downloading. The audio and image files are stored on the aggregate server. When a user views a dynamic map of the data, the information is pulled from these two sources. Also, we collected location data in two ways: from the phone internal GPS or an external GPS. Google Fusion Tables recognizes location information, but only from a single type. Thus, once data was submitted, we edited the location data to represent a single source so that Google Fusion Tables could interpret the location of the data. The majority of the work for data management and mapping was in system troubleshooting. Taking data from a phone to a Google map is now streamlined, but required multiple iterations of the process to determine the most efficient path.

When viewing the dynamic map, a mouse click shows information from the Fusion Table in a pop up balloon (Figure 16). We used HTML in order to program what types of information appears when examining a data point (Figure 17). For example, for the rare species observation submissions, we chose to pull data directly from the sampling event like date, location and any pictures taken at the site of the observation. For the avian transects, we inserted a link to the entire database of bird observations.

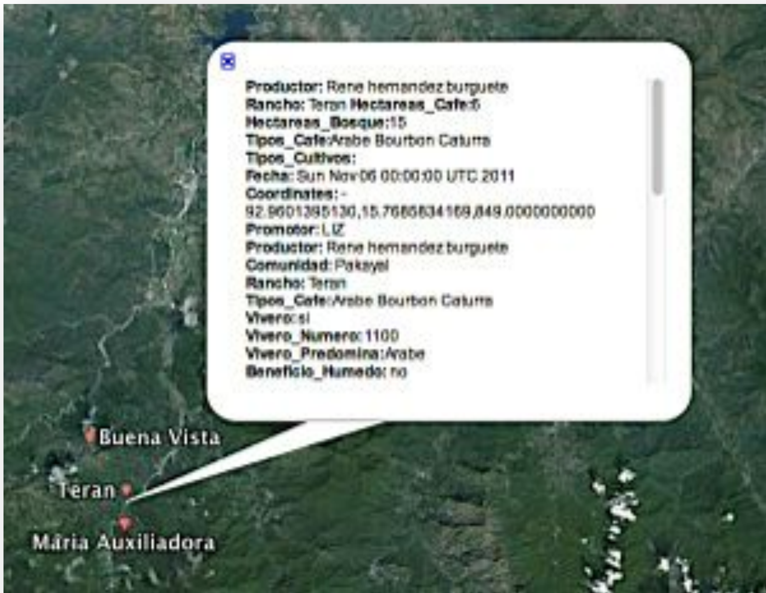

Figure 16 Pop Up Balloon Data Query: A mouse click on the data points reveals a window with information. HTML determines the style and quantity of information as well as adds links and links and files

Figure 17 HTML for Pop Up Balloon Style. Google Fusion Tables allows for custom pop up balloon design. A user can copy and paste an HTML template into the window

Presentation of Results

Once significant data had been collected, edited and visualized we made two presentations showing the results of the effort of the community monitors. We presented to stakeholders separately, giving one presentation to delegates of Comon Yaj Noptic and the conservation easement members and another to Finca Arroyo Negro. The presentations were designed to ensure that all data collected were placed in the stakeholder's possession, to explain the strengths and weaknesses of the system and to present the next steps needed to continue such a monitoring program.

Qualitative Methods: Interviews, Surveys and Participant Observation

The focus of this pilot project was to test the possibility of a nascent mobile data collection system for community based natural resource monitoring. When a technology is still in its development phase its vital to understand how users of the system are responding and what improvements can be made to help the system achieve its goals. We asked the software developers of ODK and Google Earth Engine what their main questions would be for a qualitative case study testing the feasibility of their technology. They responded with:

- If they [the user] prefer it [ODK] to their previous methods [paper], can they identify why [or why not]?
- What do they [the user] see as the pros and cons?
- Any observed or reported functionality that is missing (data types, widget types, entirely new applications) that would make their lives easier?

Pronatura Sur, as our conservation partner in the field, was also interviewed on what social aspects of the case study would be of interest. Israel Amezcua Torrijos, Regional Coordinator of the Zoque Jungle for Pronatura Sur, wanted to know the degree of difficulty in training the community monitors how to use the Androids for data collection. If the training was too difficult then would it be worth Pronatura's time to invest in the mobile system for their data collection needs? Rosa María Vidal, Director for Pronatura Sur, was interested in learning about the community's perception and attitudes towards the mobile system. Since Pronatura Sur considers itself a community based conservation organization, an evaluation on the perspectives of the community acceptance of the technology would be prudent to understand.

Our research goals were to evaluate the opportunities and barriers to implementing a mobile community monitoring system in the context of natural resource monitoring. Balancing our stakeholder interests with our own research goals we narrowed the focus of the case study to:

- Defining the learning curve for mobile data collection.
- Recording our learning experience of developing the mobile system: form building, training, data collection, aggregate management, editing and visualizing
- Investigating the opportunities and barriers on the local, regional and national scales

A review of the literature provided us with a guiding theoretical framework: the Technology Acceptance Model (Davis, 1989).

Data Collection

The methods we used to investigate our research questions were: a survey, interviews with participants and stakeholders, participant observation, field notes, document analysis and digital recording.

For all interviews we used the non-schedule standardized interview method, which requires the interviewer to create a list of desired information from each respondent but allows for freedom in how the question is formed to get that information (Denzin, 1989). This method allowed us to adjust and adapt questions depending on whom we were interviewing and how the interview was progressing. Additionally we tape-recorded each interview for later review and confirmation on Spanish translations.

Before we began the pilot we interviewed employees from AMBIO, who had previously tested the same mobile data collection technology for community-based carbon monitoring, on what types of challenges they encountered. Additionally, before we initiated training with the monitors we interviewed the employee responsible for running the community-monitoring program at Pronatura Sur to gain an understanding of what they thought the barriers and opportunities were to implementing the mobile data collection system.

After an initial indoor training on the Android phones and a basic explanation of the system and monitoring goals, we conducted interviews with each monitor to assess their level of experience with technology and monitoring. We also used this opportunity to ask what they thought about mobile data collection and their motivations for participating in monitoring. Throughout training and data collection we recorded field notes on the monitors progression and our observation on the interactions in between them, their neighbors, community members and Pronatura Sur employees. We used thick description, highlighting the things they found difficult and the things they found easy and who was supportive or interested in our study and who was not. We organized our notebooks according to objective descriptions on the right and subjective thoughts on the process on the left (Taylor, 2011, Personal Communication). Additionally we recorded the time to enter data into the phone and compared it by recording the time it took to enter the same type of data onto paper.

In order to solicit feedback that had some freedom from observer bias we designed each form to have a voice record option at the end (Schwartzman, 2008). This was for the monitors to report any problem they had with the form or any additional thoughts they had about the technology and monitoring experience.

We also used methods of participant observation during data collection. This included using the Androids to collect data ourselves alongside the monitors and to ask follow-up questions on the behavior we observed; why did you use the hard keyboard? Was it difficult for you to find that form? Do you think the dropdown option is easier than having to remember a list of species? We identified our role as the observer because the act of data collection in itself is already an action that involves observation and recording notes. Therefore it was unobtrusive to take notes during our sampling events and even during training. Our study was a test of the mobile technology so the participants understood from the beginning that we would serve as evaluative figures.

After we established goals with the monitors we left the field and returned two weeks later to conduct check-in interviews and troubleshoot technical problems. This allowed us to note what they were having difficulty with and why.

At the end of our pilot we presented the results to the participating community monitors and the delegates of CYN. After this presentation we held a discussion on the future of the monitoring program and what the delegates thought about the mobile system. We created two surveys to be distributed, one for the community monitors that used the mobile technology and the other for the delegates of CYN. We collected 5 Monitor surveys and 21 CYN surveys. The goal of the monitor survey was to quantify, using a Likert scale, how easy and useful they thought the different forms were and how easy or difficult it was to learn the various Android and ODK features (See Appendix II for further survey questions). At the end of the monitor survey were four open-ended questions asking for their perceptions on the barriers and opportunities of the system. The CYN survey did not have the Likert scale and only consisted of the same four open-ended questions.

Analysis

The first stage in analysis was to organize the different types of data we had collected into a master document. We typed up all hand written notes using italics to indicate subjective notes and regular font to indicate objective notes. Then we listened to each interview and sifted through all the video and recorded each time something of relevance to the study focus was mentioned and at what time-marker we could find it on the recording. Due to time constraints we chose not to transcribe. We translated all the survey responses and created a matrix displaying the responses to each question.

We approached open coding by first familiarizing ourselves with the data set and then using Word Processing "Review" function, which allows you to take notes on electronic documents. Coding involved summarizing and organizing the data into categories following acceptable social science methods (Wolcott, 1990). We analyzed and organized these categories using the Technology Acceptance Model (TAM) as a guiding framework (Venkatesh, 2003). This model helped shape the analytical index.

The TAM model is not traditionally used for analysis; instead it is used as a quantitative evaluation of the potential for adoption of a new technology in the workplace. Researchers use the model to help design a hypothesis and then test their hypotheses using surveys based on each variable within the TAM. However, researchers have used the TAM in developing countries to examine the potential for rural technology adoption demonstrating its flexibility (Rose & Straub, 1998). Since the context of this case study didn't fit the exact parameters of the TAM we intentionally used the model ad-hoc in an attempt to cross-reference our coding with the robust literature supporting the TAM as a model for predicting the potential for technology adoption.

CHAPTER 3: Integrative Results and Discussion

Technical and Ecological Results

Developing a Mobile Data Collection System

The results of the development of a mobile data collection system are not traditional findings, but rather a description of the eventual products and outcomes of creating a digital framework for data collection. This section will describe the outcomes and products of the form creation, database construction and database management and mapping process.

Form Creation

We created eight Xforms with 18 iterations to match with seven sampling objectives and one training objective (Table 4). Of the eight forms created, the avian transect form was the most difficult to produce requiring four iterations until it was acceptable for the field. Similarly, the above ground biomass form was difficult to create, requiring three iterations. To remedy errors and improve iterations we made 18 comment posts to the ODK Forum. Finally, we shared the completed biomass estimation Xform with the Community Forest Monitoring Working Group for other ODK based monitoring programs with Spanish speakers.

Table 4 All forms created and iterations performed to completion*

Objective	Form Name	# of Iterations
Above Ground Biomass: (Walker et al 2011)	Forest	3
Pronatura's Avian Point Counts	Gremios Mas	4
Internal Control of Coffee Operations	Control Interno	2
Rare Species Incidence	Especies Raras	2
Local Forest Take	Forest Utility	1
Pronatura's Bird Banding Protocol	Anillos	2
Habitat Type Ground Truthing	Uso De Suelo	2
Training First Time Users	Sample Monitores	2
*** See appendix for a description of all types of data collected through these forms**		

Database Construction

We created and maintained five Aggregate servers for each separate data storage need (Table 5). ODK Aggregate underwent six revisions from the start of our work to the end of data collection, changing from version 9.8 – 1.0.4. Maintenance of the aggregates, due to the constant change in versions, required constant updating and troubleshooting.

As mentioned in the methods section, the aggregate websites are hosted on Google storage space called Google App Engine. In November of 2011, this program graduated from its beta version and began charging users for certain types of usage. In some cases, publishing, downloading and viewing data from the aggregate server would exceed Google's free use quota limit and cause the website to be inaccessible for 24 hours. With a Google account we were able to monitor the usage quota and occasionally prevent overuse. While this issue was remedied in part by subsequent versions of ODK Aggregate, this problem still persists to a certain degree.

Table 5 Five aggregates created

Users	Unique Appspot ID
Pronatura	http://pronaturasur.appspot.com
Finca Arroyo Negro AC	http://arroyonegroac.appspot.com
Easements Pakayal and Nuevo Paraíso	http://servidumbre01.appspot.com
Cooperative Comon Yaj Noptic	http://cyn-sss.appspot.com
Analysis of Avian Data	http://gremiosmas.appspot.com

Data Management and Mapping

Data management for this system was carried out by use of the suite of Google tools provided. Google Docs stored the information in two ways: as a spreadsheet and as a Fusion Table. The Fusion Table was modified to be the information behind a data rich map and the spreadsheet was the raw data for downloading and analysis.

To facilitate mapping, we built four HTML templates that any user can copy into the HTML window in Google Earth. The end mapping result is described in layers of information that can be shared individually or as a group to be viewed on Google Earth (Table 6). These layers can be turned on or off to conduct analysis at the partner or regional level. For example, one can view all of the avian data from within Arroyo Negro, but then turn on the layer from the surrounding sites for a regional analysis. Additionally, these maps can be embedded into websites and will represent changes or updates seamlessly. Notably, these maps can link to raw data allowing for rapid or in depth analysis for the data.

Table 6 Google Earth map layers and features

Layer Name	Information Displayed	Layer Features
Uso de Suelo CYN	Land use characterization on CYN parcels	Images at 4 cardinal directions, location, estimation of canopy height
Uso de Suelo AN	Land use characterization in Arroyo Negro	Images at 4 cardinal directions, location, estimation of canopy height
Uso de Suelo Paka	Land use characterization in Easements Pakayal & Nuevo Paraíso	Images at 4 cardinal directions, location, estimation of canopy height
Gremios Mas AN	Avian point counts within Arroyo Negro	Distance calculation of transect, images of habitat at transect, evidence of rare species along transect, link to file of all avian observations at that site
Gremios Mas Servidumbre	Avian point counts within Pakayal and Nuevo Paraíso	Distance calculation of transect, images of habitat at transect, evidence of rare species along transect, link to file of all avian observations at that site
AN Biomass	Biomass estimations for forest plots	Habitat type, image of data collection, link to file of DBH measurements and biomass calculations
Observación General AN	Point observations within Arroyo Negro	Image of observation, location, link to recording of observer if any
Observación Pakayal	Point observations within Easement Pakayal	Image of observation, location, link to recording of observer if any
Ecotourismo	Observations with tourism value	Image of site, location, link to recording of observer if any

Huellas	Observations of notable species	Image of track, location, link to recording of observer if any
Control Interno	Coffee operations data	Name of parcel, name of farmer, images of farmers, nursery and *benficio humedo*, link to all internal control data

Mobile Data Collection Results

Both targeted and surveillance monitoring methodologies were employed for data collection. At the four study sites of Finca Arroyo Negro, Easements Pakayal and Nuevo Paraíso and Comon Yaj Noptic partner farms, 190 total sampling events were carried out representing 76.3 hrs of effort, 555 points of data at an average total cost of US$0.51 per sampling event or US$1.25 per hour spent collecting data (Table 7). Surveillance monitoring was conducted more frequently than targeted monitoring (173 surveillance sampling events compared to 10 targeted). Monitors were paid for their effort consistently using Pronatura's compensation rate of $50MX per sampling day. The Arroyo Negro monitor conducted sampling as part of his park guard responsibilities and was not paid an additional amount. The Comon Yaj Noptic monitor interviewed partners of the cooperative as part of his responsibilities as "promotor" or internal employee and representative and was not paid an additional amount.

Table 7 Total sampling effort, location and cost

Sampling Objective	Monitoring Type	Number of Sampling events	Time dedicated (hrs)	Location*	Cost $US/sampling events**
Avian Biodiversity	Targeted	7	19.0	AN, PA, NP	3.56
Above Ground Biomass	Targeted	3	7.1	AN	1.52
General observation	Surveillance	69	3.5	AN, PA, NP	35.05
Rare Species	Surveillance	11	0.5	AN, PA, NP	5.59
Land Use	Surveillance	78	7.8	AN, PA, NP	39.62
Forest Utility	Surveillance	15	37.4	AN, PA	7.62
Internal	Survey	7	1	SF	3.56

Control					
Total	**--**	**190**	**76.3**		**95.52**

***AN – Arroyo Negro**
PA – Easement Pakayal
NP – Easement Nuevo Paraíso
SF – Colonia San Francisco (Comon Yaj Noptic Partners)
**** The total cost per sampling event was calculated by dividing total number of sampling events by the total cost.**

For the above ground biomass (AGB) estimation in the shade grown coffee plot, all trees above 5cm DBH were measured for a total of 24 trees. The species identified were *Ulmus mexicanus* and *Inga spp*. The plot AGB was estimated as 43.8 metric tons, which represents 273.8 t/ha in similar habitat (Table 8). In the cloud forest plot, all trees above 5cm DBH were measured for a total of 148 trees. The species encountered were *Ulmus mexicanus*, *Ficus spp*. and a variety of palm and unknown woody broadleafs. The plot AGB was estimated as 69.2 metric tons, which represents 432.5 t/ha in similar habitat (Table 8). Palms were excluded from the biomass calculation because of their minimal contribution and the lack of height data recorded. In the pine-oak forest plot, all trees greater than 5cm DBH were measured for a total of 86 trees. Species were identified as either pine, oak or woody tree. The plot AGB was estimated as 17.6 metric tons, which represents 110.3 t/ha in similar habitat (Table 8, following page).

When compared to above ground biomass estimates in similar tropical forest types, the results we obtained are similar, except for the cloud forest plot, which is slightly larger than normal tropical moist forest averages (Brown 1995). While we did not collect enough samples to create a rigorous analysis, a few trees were well outside or at the acceptable limits of the Chave *et al*. (2005) equation of 5cm-165cm. A single *U. mexicanus* of five meters in diameter was observed, but was excluded from the biomass estimation. It is unclear whether more samples in this cloud forest habitat would result in an even distribution of trees > 1m, but it might be assumed that with continued sampling, the average would represent regional averages.

Table 8 Above ground biomass estimations for all sample plots

Plot	Plot AGB (metric tons)	Metric tons/ha	CO2 emissions if burned (metric tons)
Café	43.8	273.8	160.8
Cloud Forest	69.2*	432.5	254.0
Pino Encino	17.6	110.3	64.8
*** Palms were excluded from the calculation**			

Community monitors carried out seven avian sampling events with the Android phones. 57 different species were observed out of a total 132 individuals. Observations were made on four different avian transects at three different sites in five separate habitat types. The location data from the point counts and land use data were combined to create transect data layers in Google Earth, with links to the site-specific avian data.

Sampling for evidence of local forest use, or forest utility, was carried out a total of 15 times on 10 distinct sampling routes for 37.4 hours of search effort in sum. Forest utility, calculated as number of trees per unit effort search (hours walking at a constant rate) across all sampling sites was 0.27. All but one of the search events resulted in an observation of cut trees. Within the conservation easement Pakayal, forest utility was 0.38 and at Arroyo Negro, no cut logs were observed.

Land use data was collected at 78 points, 33 in Arroyo Negro, 36 in easements Pakayal and Nuevo Paraíso and nine among the Comon Yaj Noptic partner sites. The dominant habitat sampled was shade-grown coffee with multiple shade species across all sites. In total, 12 habitat types were sampled. The points were distributed across 94.6 square kilometers. Additionally, land use data was collected at each of the avian point count locations in Arroyo Negro and Pakayal to create data rich transect maps. Overall, 312 images of habitat were taken using the built in Android camera.

The internal control questionnaire was administered to seven cooperative members over a two-day period. Twenty-six questions were administered, which highlighted the different accounting and environmental aspects of shade grown coffee operations as well as photo-documented key elements (Table 9, following page).

Table 9 Sample of the information in Internal Control

Internal Control Pilot Questionnaire Information
Geographic location of parcel
Name of producer
Name of coffee cooperative representative
Number of hectares in production
Number of hectares in conservation
Presence or absence of fresh water source
Presence or absence of nursery
Dominating cultivar in nursery
Images of the nursery
Presence or absence of drying patio, current status and images
Presence or absence of fermentation tanks, current status and images
Presence or absence of coffee masticator, current status and images
Presence or absence conservation practices like live fences and protected streams
Image of coffee producer and family
Audio observations from the cooperative representative

Throughout the course of field sampling monitors collected 69 total general observations. The observations included important water resources, ecotourism sites, evidence of rare species, evidence of disturbance like land slides and fires, disease on coffee plants, and evidence of biomass field sampling. Various rare or notable species were encountered of 19 total species registered, some with protected status (Table 10,).

Table 10 Species Observed Throughout Sampling Effort

Common Name	**Species Name**	**How Observed**	**# of times Observed**	**IUCN Status**
Black Hawk Eagle	*Spizaetus tyrannus*	Visual	1	Least Concern
Collared Trogon	*Trogon collaris*	Visual	2	Least Concern
Grey Hawk	*Buteo nitidus*	Visual	1	Least Concern
Jaguar	*Pantera Onca*	Track	1	Near Threatened

Ornate Hawk Eagle	*Spizaetus ornatus*	Feather	1	Least Concern
Palm	*Ceratozamia spp.*	Visual	1	Endangered
Peccary	*Pecari tajacu*	Track	1	Least Concern
Tapir	*Tapirus bairdii*	Track, Feces	3	Endangered

Across all sampling methodologies, users sometimes opted to record audio resulting in 63 geo-referenced audio clips. These clips can be accessed from Google Earth when clicking on the data point. We initially designed the forms to end with a verbal feedback option. This was based on the methods from a similar case study on automating internal control at coffee cooperatives in Oaxaca, Mexico (Schwartzman 2008). The researchers found that the verbal feedback option provided an opportunity for the user to express their opinion without observer bias. However, the monitors included information in these audio clips ranging from general visual descriptions to site background, representing a type of oral ecological history (Table 11).

Table 11 Examples of observations recorded through the audio feature by monitors

Location	Quotation
Pakayal	*Here we are at the spring, there is a connection to the housing for the workers, to another location outside of this property and the provide water for the coffee plants. They are using the water service, which is fundamental for living.* *This landslide was from this year, about 6 days ago; it destroyed 35 plants of coffee. Also there was a landslide here before in 2010 in the exact same location.*
Arroyo Negro	*Right now we are viewing a track of a mapache, not sure if it's a juvenile or adult but the track is very large.*
Ejido Nuevo Paraiso	*Here we are looking at a MIAF, which is a combination of corn, squash and beans in between fruit tress that is fundamental for us and conservation of soils. It was previously forested with pine-oak but has been cut down to plant the MIAF. On the outside there is reforestation of previously cut areas.* *We can see here was a fire many years ago; this tree was previously a pine that finally fell over due to the burn. Now there is a small fire-gap that will hopefully prevent the spread of fires in the future. Little by little we are overcoming this bad custom of not managing fires.*

Ecological and Technical Discussion

Developing a Mobile Data Collection System: Successes and Challenges

The goal of building a mobile-based data collection system was in part to test its strengths and weaknesses from a technical, ecological and social perspective. As the system was used and stressed we attempted to view how these data might be used, by whom and what potential they could have to fill knowledge gaps.

Form creation

Once initial hurdles were overcome, form creation helped facilitate data collection. At project outset, we initially planned on conducting one or two types of data collection, but the ease of adding simple data collection methodologies facilitated at total of seven types of data being collected. As non-programmers, the resources were available for us to learn how to create quality digital questionnaires and then correct errors and improve functionality. However, some advanced techniques were out of our ability and if desired may require a professional form designer at an additional cost. Additionally, some ecological methods were not as well matched with a digital form. The avian point count form, for example, was the most difficult to create. The large number of questions and repeat observations stressed the limits of the form building software. Yet, once refined, the benefit of large quantities of data collected digitally was obvious, as hours of data entry and error introduction was removed from the data collection process. Overall, form creation is a replicable process for any lay user. The resources and ease of use are only likely to improve. Of course, form creation is carried out on a computer, not the mobile devices. While this may change in the future with more software companies offering mobile data collection services, the need of a computer might be prohibitive for some users. A suggested model for replication is therefore a centralized team of project facilitators that has access to computing equipment, Internet connection and technical competency. This monitoring team can facilitate the mobile data collection process. In our experience, Comon Yaj Noptic or Finca Arroyo Negro could both meet these requirements, but perhaps it is unfeasible in less centrally organized locations.

Database Management

Database management presented the biggest challenges in terms of technical aptitude. The changing requirements and versions (all written in English) create a large obstacle for the ability of communities to truly run this type of monitoring system. In this case, an individual capable of keeping up with a changing computer system to ensure key functionality like security, access and a free service is needed. Nevertheless, in the previous community based pilot programs, groups like Pronatura and Ambio have used a model of training team leaders in the community. Building computer technical capacity could be a reasonable extension of these training programs showing trust in communities to not only collect data, but manage it as well.

The data storage quotas monitored by Google seriously questions the use of this system by a small rural community. The charges are designed for small web application designers who are turning a profit by storing data on Google App Engine. From conversations on the ODK community forum it seems that the quota limits was an unexpected change in the Google App Engine system. While Google.org collaborated with ODK to create their programs, it seems that the Google.org team does not have control over the App Engine department. When I questioned the new quota limits the lead ODK designer responded saying:

> Google has radically changed the usage limits on App Engine in the last week. Originally, we had hoped that GAE would provide a free hosting solution for most light uses and that only intensive campaigns would require paying for service. It is now becoming clear that even a small data collection effort will likely need to pay for the service to the order of USD100 to USD200/year. Although this is not an outrageous amount, it does change the model we had hoped for. Unfortunately, all other cloud solutions that are out there are likely to be at the same cost or higher. Of course, we always have Aggregate for your own server, but that raises the bar for technical support and increases costs in another way. Thus, there is no solution right now that will get us back to where we were until last week. We are working on some other possibilities but those are likely some distance away. (Geatano Boriello, Personal Communication 2011)

It seems that for any cloud based storage system, users of ODK might run up against charges. To pay US$200 per year could be an unsurpassable barrier for rural communities if no financial gain was apparent. We will note, however, that directly after the change in the Google App Engine billing system, members of Google.org contacted us to field test a new model of ODK Collect. This version is designed to skip ODK Aggregate and instead use Youtube and Google Picasa to store video and images. The quotas on these servers are larger and free, like most Google applications. At this time, testing is continuing, but it seems that Google.org is committed to finding a free storage solution for limited users. From our calculations from monitoring our usage levels, if one used ODK to collect mostly numeric data and some images, one would never exceed the usage quotas of Youtube and Picasa. However, more research needs to be done to calculate what the quantities and types of data that could be collected without exceeding the free usage limits.

Ecological Data Collection in a Mobile-Based Community System

The dominance of surveillance compared to targeted monitoring is consistent with theory that predicts that less rigorous methodology will produce more observations (Wintle, 2010). Our sampling protocol consisted of more surveillance methods than targeted, but any one surveillance method was carried out more than any targeted method. Chief of concern for surveillance methodologies are accuracy of data and weakened power of analysis (Wiersma, 2010). Therefore, safeguards like recording spatial data and images are crucial to the validity of the land-use classifications and species observations that were made. Finally, while surveillance monitoring resulted in more sampling events the number of observations was greater among the targeted methodologies. This demonstrates that surveillance monitoring may result in a far greater sample size in a mobile community monitoring system, but targeted methodologies can produce data rich sampling events.

The paragon of mobile-based community avian surveillance monitoring is the Cornell lab of Ornithology eBird program. To address the data concerns of millions of opportunistic data, eBird employs complex statistics screening and over 500 regional volunteers who spot check for erroneous outliers from volunteer users who use the web to submit avian observations (Bonney, 2009). The difference between eBird and the system that we have created is the use of open source tools and a more in depth sampling methodology. The eBird program asks the data collector to record the bird species and location and uses this information to assess migration patterns and species distributions (among other analyses) (Bonney, 2009). Pronatura's training program for community monitors allows for rigorous point count methodology where data like habitat characteristics and avian behavior are recorded in addition to species and location. The use of open source tools like ODK for avian monitoring is compelling because regional users can adapt a standard methodology to collect additional and relevant information like rare species and forest utility. Compared to a closed system like eBird, the system we piloted demonstrates the ability for more locally relevant data collection.

Methods like general observations and land use mapping were quick, easy and encouraged continued use. These forms (observation and land use) were collected much more than any other form (78 and 69 compared to seven, three and 15). By adding a data collection tool that allows monitors to make valuable and daily observations about natural resources, traditional ecological knowledge can be captured. The mobile data collection system created a path for daily observations to be recorded, stored, and shared. Over time, as observed by the breadth and depth of data collected, a group of monitors can amass a substantial data set.

The forest utility sampling methodology underperformed as an efficient means of data collection. It was far underused as a stand-alone methodology, but perhaps provided one of the most interesting results in terms of an important REDD+ vertical as it can represent an indicator of leakage and forest take not observed by satellite imagery (Asner 2005). All but one of the recorded search efforts resulted in no observations of cut logs indicating well-conserved forest. This low rate of forest utility could be due to underreporting or misunderstanding of the method. While we observed local forest take for wood burning stoves throughout the region, the forest utility surveys rarely encountered evidence of deforestation. We may have been experiencing a desire to underreport negative deforestation rates by the community monitors (Campbell 2009). While Danielsen (2010) demonstrated no significant difference between community and expert reporting of forest utility, without more sampling it is impossible to claim that the rates we calculated represent a regional average. By inserting this methodology into the avian transects, however, this information was captured effortlessly and in a replicable fashion. Perhaps a standardized transect methodology for sampling forest utility is more effective in capturing accurate results. More research into determining local perspectives of sensitive data types like local deforestation is needed before designing future forest utility methodology.

The audio record option was intended as feedback on the user experience and technical problems encountered on the Androids but the results resembled more of an oral ecological diary. For example, we observed that after collecting a sample on a landslide the monitor began to explain a short history of the area and take note of previous landslides (for more examples see Table 11). Recording the ecological history of community members is cited as a very effective community monitoring method due to its low costs and breadth of coverage (Danielsen, 2005). These audio feedback results demonstrate a way ODK could be built to provide a space where the monitor could voice record items of ecological significance and tie that to a specific location to be visualized or analyzed later.

Monitoring Above Ground Biomass: An Example of How a Potential REDD+ Methodology Interacts with a Mobile Based Data Collection System

For above ground biomass estimation we set out to use a sampling methodology designed for community monitors. The Walker *et al*. (2011) sampling methodology requires only DBH measurements. The total materials we used were one Android phone, one GPS, one diameter tape, one 20-meter measuring tape and string for additional measurement. The phone's internal GPS marked the plot center then prompts the user to record the species or functional group and the DBH of all trees within the plot. The form is designed with an autocomplete function so that when a user begins to type the name of a tree, its species name, common name or functional group, a list appears of which the correct species is selected with a touch (Figure 18, following page).

Figure 18 An example of the predictive text feature for above ground biomass measurements. Image 1: The prompt for tree name and DBH. Image 2: the user enters "l" and "i" and a list of matching options appear. Image 3: The user selects the desired response with a touch ten moves on to the next question.

This predictive search function reduces error and allows for users with different ecological knowledge levels to arrive at the same conclusion. When the plot is finished the monitor can take a geo-referenced image of the habitat type as well as demonstrate evidence of data collection. After the three plots were sampled, the data set held 258 observations. Using the online database the data are instantly represented in spreadsheet format instead of needing to be manually entered by hand.

The Sierra Madre presents a challenge for biomass estimation because of its diverse habitat types. In the same sampling area, we encountered pine-oak forest, shade grown coffee and montane cloud forest. Nevertheless, the digital uploading process allows for conditional use of functional group specific allometric equations. After data upload, the Chave *et al*. (2005) allometric equation for estimating biomass is applied to the moist tropical tree diameters to produce a table of contribution to above ground biomass for each tree. Conifer biomass estimates are calculated using the FAO equations (Brown, 1997). The above ground biomass column is then instantly summed to present the plot level biomass and carbon dioxide contribution estimates. With data entry and analysis becoming near real time, the analysis can take on more meaning like examine outliers and check for errors.

Simultaneously, the database allowed for these data to be represented as a map, where a user can download the raw data and verify the estimations. Doubts in accuracy are real and more comparative research between expert and community data collection are certainly needed for this particular methodology (Danielsen *et al*. 2010: 88-112). However, because of the near-real time data visualization, external actors have the potential to verify the biomass analysis. Pictures of the data collection and habitat, as well as access to the raw data allow for transparency and accountability of data collection.

One of the areas of potential for the system we tested is the ability to combine multiple sampling methodologies for a more powerful analysis. By collecting large amounts of fine scale land-use estimations and images, the biomass estimations can be extrapolated to areas of similar habitat for broader, more refined biomass estimation. By mapping habitat type and collecting biomass data, researchers could estimate biomass over ground verified habitat polygons. Further, by combining this ecological data with economic data from the coffee internal control questionnaire, analysis could be carried out that compares coffee certification requirements and levels of biodiversity of carbon storage. For example, the question could be asked: Does compliance with more environmental coffee certifications result in increases biodiversity or ecosystem services? The degree of environmental certification compliance could be compared to regional biodiversity or above ground biomass to estimate the relatedness between rigor of coffee certification and environmental services. This hypothesis driven approach could perhaps be understood with large quantities of community-produced data representing a novel and low cost methodology.

It is this kind of ease of analysis and data sharing that is of great interest for the community forest monitoring context. After using this system, we posit the role of an agency like CONAFOR could change from investigator to verifier. At the REDD+ workshop, a chief concern was doubt of CONAFOR to be able to manage the huge amounts of forestry data that would exist in a national MRV system. However, as members of the workshop commented, if CONAFOR's job changed for data collector to data verifier (from MRV to just V), perhaps the MRV task could be overcome. This is the very system that the Suruí tribe in Brazil has implemented. They have produced and published a dynamic Google map that displays biomass estimations in their forested lands in anticipation of payments for carbon sequestration.

Visualization and Analysis

Mapping data with Google Earth and Fusion Tables was intuitive. While certain functions, like coding in HTML were prohibitive at first, the template method removed this barrier. For this obstacle, an initial investment in setting up the mapping system where inserting HTML templates is a first step. Then, a user simply has to add data to the Fusion Table to gain benefits of the advanced dynamic mapping functions. The final format of data as a dynamic data rich map was most intriguing as a methodology for a data sharing and verification process. The data format is static enough that monitors must carry out standard methodologies resulting in replicable data. However, the flexible system that Google Earth provides allows users to withhold sensitive data and transform data into more rigorous analysis. At the REDD+ workshop, an unanswered question was what methods would be used to monitor REDD+ variables and what system would be used to capture the data. Google Earth provides an elegant solution to this problem. The Google system is free and therefore inclusive. The design of Fusion Tables encourages similar types of data collection yet allows for individual users flexibility in customization. Google.org's message at the workshop was "use our system" for MRV needs. After my experience we can certainly see this as a technical possibility, while not yet considering the political context.

Recommendations for Open Data Kit

Our pilot allowed us unique insight into the applicability of ODK in the context of environmental monitoring as well as use by community volunteers. As a separate deliverable, we prepared a set of specific feature requests and bug reports to the developers of ODK. We hope that our Xforms and our pilot project will be shared with the ODK community and improve the use of ODK for environmental applications.

Qualitative Results and Discussion

The results of this project component are split into two analytical sections. For both sections there will be an analysis and discussion. The first section focuses on the Learning Curve and the second on the Technology Acceptance Model (TAM).

Learning Curve: Training of Users for Mobile Data Collection

To determine the possibility of scaling up this mobile community monitoring system we studied whether the learning curve for the mobile data collection was simple enough to be worth replicating at a greater scale. One of the benefits to CBNRM is that while initial costs of implementing the program may be high, over the long-term they tend to be lower than using expert monitors (Danielsen 2005). If the effort and resources needed to train community members in the use of the phones is too high then it could take longer to offset the initial costs in future savings. The costs might not be worth the benefits. Additionally, the motivation of the community members to participate in a mobile monitoring system will be linked to the effort needed to learn the mobile method (Davis, 1989). If the mobile method were too difficult to learn then the community would be likely to loose motivation.

Each monitor successfully completed the first two stages of the learning process, phone and ODK basics. In the third stage, independent data collection, only two out of the four monitors collected data outside of our supervision. In the second section, the possible motivations and influences behind this will be discussed in more detail. The results suggest that the costs for training the monitors would be within reason (see Table 7) and the learning process for the Androids is not difficult and therefore would not be a deterrent in the motivation for participating in a mobile monitoring program.

The monitors were classified into two different categories regarding their experience with technology and monitoring. There were two monitors with minimal technological experience and a rudimentary understanding of monitoring. They were classified as the “beginners.” The other two monitors either had previous experience with computers or touch screens and had both been monitoring since the inception of the Pronatura avian monitoring program. These monitors were classified as “intermediate.”

Phone Basics

The initial part of the learning process for the monitors involved mastering the basic operations of the phone: what each feature on the phone did, how to turn on and off the phone, how to open the ODK application, how to charge the phone and basic keyboard operations. Three out of five monitors responded in the survey that learning the basic operations were "very easy," while two out of five thought learning to use the keyboard was "very easy."[1] The monitors generally understood the basic operations of the phone in the first hour of indoor training and mastered them during the second day of outdoor instruction. There was a unanimous preference for the hard keyboard. One monitor stated during training that his reason for this preference was that, "my fingers don't fit the screen."

During an interview with an AMBIO employee they mentioned that the monitors thought that the small size of the keyboard made it difficult to enter data. A Pronatura employee also cited this as a potential barrier to learning how to use the phones and suggested that tablets were more suitable for mobile data collection. While the preference for the hard keyboard was evident there was no evidence that the size of the keyboard hindered data collection. Lastly, previous studies mention the difficulty in teaching users with no previous keyboard experience the concept behind the QWERTY keyboard (CIGA-UNAM, 2011). However during our pilot there was one monitor whose first QWERTY keyboard experience was during the indoor training with us, when asked the next day whether the sequence of letters on the keyboard was confusing or difficult to understand he replied that he wasn't having any difficulty.

ODK Basics

Stage two was comprised of mastering the ODK application basics. This included: understanding the GPS function, advancing and reversing within the form, selecting forms, navigating the menu within the forms and saving forms. While all monitors did master the very basics of this stage, the monitors in the beginner category didn't advance to higher-level ODK functions like navigating within an active form. Yet one of the monitors in the beginner category still managed to collect data independently of our supervision.

[1] The survey was distributed to five monitors. The fifth monitor was an employee of Pronatura that briefly used the phone for data collection in the field. However I was not unable to spend time observing his use nor did I have an opportunity to interview him so his learning curve is omitted from this study, but his survey results are included in the totals.

Four out of five monitors ranked the learning of the ODK functions as either "very easy" or "easy." The only exception was finding the forms in the ODK application in which the majority ranked it as "not easy but not difficult." This was confirmed with the beginner monitors in whom on separate occasions both managed to delete forms from the application. When asked how it happened one replied with, "I just went to open it one day and it was gone."

The eHealth Nigera Training Manual for ODK (2010) mentions that there should be an emphasis on training the users in how to deal with ODK error prompts. They even suggest grabbing the phones during the users training and causing the prompt to appear and then passing it back to them to solve. Our results suggest that placing an emphasis on troubleshooting with the monitors during training could have avoided the deletion of forms.

Before the training began a monitor expressed that he might find it difficult to, "understand the English prompts, but that is why you guys are here, to help." To address this potential barrier we left a sheet with Spanish translations of the English prompts and potential error messages with one of the monitors with the least experience in technology use. However this monitor was observed during the check-in to still have difficulty with the ODK basics due to the English error prompts. Therefore a cheat sheet was not sufficient to overcome this learning hurdle. Jeffery-Cocker, Basinger & Modi (2010) mentions this same challenge with the users in their case study. They suggest multiple language functionality as a priority area for development within the ODK platform. Our study confirms this need as well, however ODK is aware of this issue and has committed to further developing the language function.

Individual Data Collection

Learning stage three was defined as whether the monitor collected data independently from our supervision. To collect data independently required an understanding of the hardware and software basics plus knowledge of when, where and why to use the phone for data collection. During our field training none of the monitors were observed to take initiative to record data. Tentatively one had suggested, "is this something to record?" but the majority of data collection had to be instigated by us during training. There are multiple external variables that influenced this learning stage and it can't be defined as those who collected data learned this stage and those who did not collect data didn't learn this stage. These factors will be discussed in further detail in the following section.

Variables Influencing Technology Acceptance

To analyze what the opportunities and barriers were in the acceptance of this mobile system for community monitoring we analyzed our qualitative results loosely using the Unified Theory of Technology Use and Acceptance (Figure 3 &4, Table 13). The following discussion defines each variable using the literature (Table 13) and then discusses each theme that was analyzed using that variable (Table 14). Like mentioned in the literature review, this model is normally used to define survey questions, so we took each variable and defined it in the form of survey questions in the context of our project. This guided the analysis that follows.

We excluded the variables of gender, age, experience and voluntariness of use because the sample size was not large enough to make an inference on the role these variables played on individual technology acceptance. Instead, this case study provided depth concerning an individual's decision for technology adoption allowing us to investigate how the external variables could influence an individual use of the system. In our conclusion we use our literature review of the key components needed for a successful CBNRM to add perspective to the discussion on the external variables (Table 12).

Table 12 Synthesis of the external variables used for analysis (Venkatesh 2003)

Variable	Summary Definition
Social Influence	Degree to which an individual perceives that important others believe he or she should use the new system
Facilitating Conditions	Degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system
Performance Expectancy	Degree to which an individual believes that using the system will help him or her to attain gains in job performance
Effort Expectancy	Degree of ease associated with the use of the system

Table 13 Example of the variables interpreted in the context of mobile community monitoring

Variable	Relevant Components	Definition in the Context of Mobile Community Monitoring
Performance Expectancy	Perceived Usefulness	Using this mobile system will improve my ability to collect useful data
	Extrinsic Motivation	The results of using this system will be highly valuable to generate good monitoring data
	Relative Advantage	This phone is better than using the paper form
Effort Expectancy	Perceived ease of use	This mobile monitoring method will be easy to use
	Complexity	This mobile monitoring method will be difficult to understand and use
Social Influence	Subjective Norm	People in my community think I should/shouldn't use this mobile monitoring method
	Social factors	I believe that my interpersonal interactions with my community will influence my use/non use of this mobile monitoring method
	Image	The use of this mobile monitoring method enhances my status within my community
Facilitating Conditions	Perceived behavioral control	The physical resources, such as phones and computers, are available/not available to use for mobile monitoring. If the resources are not available but were to be made available I would use them.
	Compatibility	Using this mobile system will accomplish my needs for data collection and support my values (environmental, economic gain)
	Facilitating Conditions	Guidance and instruction are available for me to understand how to use this mobile monitoring system

Facilitating Conditions

Venkatesh (2003) defines this variable as, "the degree to which an individual believes that a organizational and technical infrastructure exists to support the use of the system." In essence, if an individual knows there will be guidance and instruction for learning a new system, and the continuing appropriate physical resources such as software updates or replacement parts, then they are more likely to adopt the system. Successful community monitoring projects ensure that the support in aspects related to community data collection should come from within the community itself in addition to local NGO organizations (Blom, 2010).

Perceived Lack of Resources

The current avian community monitoring program run by Pronatura provided the monitors with the necessary resources to complete their monitoring. This included binoculars, GPS units, field guides and data collection forms. These resources are intended to reside in a central location: at our field sites it was the offices of CYN, for the monitors to share. While this was the intention of the Pronatura program the perception on the resource availability of the monitors was different. One monitor noted that, "I never have a chance to use the GPS, without the GPS I don't know my points and I can't do my transects every month." Because electronic submission is how the monitors share their data with Pronatura a monitor expressed their frustration behind sharing a computer with the administrative tasks of the cooperative for data entry.

In a mobile monitoring system the physical and technical resources needed to sustain the program should to come from a local conservation program (Personal Communication, Esquivel 2011; Danielsen, 2008), ideally Pronatura. However, involving the community in the maintenance and technical expertise of using the system is vital if sustainability is desired (Blom, 2010). The situation in this case study suggests that the potential for organizational support could come from Pronatura, as it has in the initial donations of field equipment. However the perception of the monitors we interviewed is that the support has not continued. The surveys with the monitors and CYN delegates all demonstrated that the community perceives there is a lack of financial and structural support for the mobile system, indicating that the community doesn't think of itself as a potential source of support either. These are important challenges to be addressed in any form of technology adoption; if the tool is introduced without training and continuing support then it will remain unused.

Organizational Motivation to Provide Resources for a Mobile System

Pronatura played a pivotal role in the initiation and intermittent maintenance of the avian community monitoring program but the program is not a priority in regards to Pronatura's larger monitoring projects. They received funding in 2005 from the Mesoamerican Biological Corridor to increase their involvement in long-term monitoring of protected areas (Macías & Martinez-Fernandez, 2009). However one Pronatura employee mentioned how, "community monitoring is a small part of the larger partnership we have with CONANP in long-term monitoring." This employee described how the monitoring program had actually lost momentum since its inception in 2005 and was, "in need of another training for the monitors and better management and use of the data." This employee noted how the mobile system could help Pronatura improve the monitoring program through facilitating better "flow of information" indicating that the organization sees the benefit to the mobile monitoring system but may be stretched in its available resources for implementation and maintenance.

Ubiquity of the Mobile Device

Moore and Benbaset (1991) note that a new technology must be compatible for the user under the facilitating conditions, this means it is consistent with needs, values and experiences of the user. Using the Android phones to facilitate this mobile monitoring system demonstrated a high degree of compatibility among the monitors. Each monitor owned or knew someone who owned a cell phone. The complexity of the cell phones differed for each monitor but the familiarity in the functionality of the device was the same. The device also had a primary need (communication) that surpassed the possible secondary use (data collection). Since the idea of this system is that a monitor could eventually use his or her own mobile device to collect data while tending to their primary jobs such as caring for coffee plants or conducting guard rounds in park reserves it appears that there is a high compatibility of the system with the monitors daily lives, experiences and use. Lastly, the cooperative recently bought a computer from Pronatura that it intends to use for data entry; this increases the familiarity with the additional equipment needed in the monitoring process.

Data Collection as Part of Job Requirements: Existing Infrastructure for Facilitating Conditions

One monitor was a park guard at the field site of the private Finca Arroyo Negro. His job description was to conduct vigilance rounds on the property to report illegal timber cutting, hunting and evidence of fires. This condition created a top-down facilitation in using the mobile data collection system because it was entirely compatible with his job description. This might be one of the central factors that led this monitor to be one of the two that collected data without our supervision.

The park guard monitor along with another monitor received additional (to that of Pronatura's) monitor training from the Comisión Natural de Areas Protegidas (CONANP) on different forest resources like mammals and reptiles. These two monitors were the ones to collect data without our supervision. It appears that the implementation of the mobile system within CONANP's park guard network could provide an excellent facilitating condition for the acceptance of this mobile system. As one Pronatura employee noted, their larger monitoring program consists of a collaboration across various conservation organizations including CONANP, which positions Pronatura with the possibility of collaborating on the integration of the mobile system into their training program.

Social Influence

Social Influence is defined as, "the degree to which an individual perceives that important others believe he or she should use the new system" (Davis, 1989). If an individual believes that their boss, superior or community leader thinks they should use the new system then they are more likely to adopt. The personal and communal motivation for monitoring, influenced by the social factors, are strong indicators for the success of a mobile community monitoring program.

CYN Cooperative Support for Mobile System as a Platform for Internal Control

The cooperative plays a central role in the adoption potential of the mobile monitoring system. Seven of the Pronatura avian monitors are part of the co-op, including two out of the four monitors we worked with. Additionally, the employees of Pronatura usually meet with the monitors to discuss progress and methodology in the offices of the co-op. At the Café and Cambio Climatico (Coffee and Climate Change) conference at the end of November in nearby

Jaltenango, three coffee cooperatives in the region met to share ideas on coffee production needs and vulnerabilities, the market and the role climate change plays in conservation coffee. CYN, noted by guests and presenters, stood out amongst the three cooperatives as the only cooperative that participated in this monitoring program (however there are other coops not present at this conference that participate in community monitoring). The Director of the cooperative is very supportive of conservation and a partner in the same civil organization, "Coffee Producers in Promotion of Conservation" as one of the monitors we worked with. When we presented the possibility for using the mobile system for internal control he was enthusiastic and provided us with transport and the time for one of the cooperative member-monitors to test the system. However, since it is a cooperative, the leadership rotates every three years indicating that one director's interest in conservation may not carry over to the next director.

The monitor's perception of CYN's support of the Pronatura community monitoring program was mild. They identified themselves as having the minority perspective (as in those that thought monitoring was of significance and worthy) out of the members in the cooperative. One monitor said during our interview, "of course we only monitor because its fun, it's a lower priority." Three monitors noted in their surveys that a barrier to implementing this mobile data collection system would be convincing others in the cooperative to support the initiative. There was some creative discussion around how to get others involved, one monitor noting, "we could take pictures of birds native to each community in which there is a delegate of CYN and hang them in the office, that way people could see how beautiful and unique they are." However engagement ideas aside, the monitors did not see CYN as a supporting social presence.

The results from the survey administrated to the delegates of CYN after our presentation on internal control findings and ecological data collection demonstrated that the cooperative was interested in the mobile data collection, but for the purpose of internal control and not necessarily for conservation outcomes. However in many of our discussions with the Director of CYN he mentioned the possibility of using the visualization capabilities of the mobile system to demonstrate to clients their conservation practices thus increasing their potential revenue from certifications of conservation friendly coffee production.

The survey also revealed that many delegates thought a barrier to the system was lack of resources and funding (Appendix II). The discussion following our presentation focused on whether Pronatura could provide these resources and if not then they [the cooperative], as one delegate put it, "have a lot of work to do, government can handle the monitoring and while it's interesting, it's not a priority." There was a long monologue in which the Pronatura employee defended the role of ecological monitoring as having use to the cooperative outside of conservation motivations. He used the example of monitoring for climate change to provide early warning on how it would affect their crops. However the overall mood in the room was that ecological monitoring is a second priority.

Another noted theme across the CYN survey responses was the disunity between members of the cooperative (Appendix II). They believed that there was no consensus, unity or common understanding on goals within the cooperative. This lack of cohesiveness suggests that the disagreement amongst the delegates runs deeper than just whether monitoring would be a proper use of their time and resources. Other CLP researchers in the same region noted this theme as well, however their research demonstrated that there were cooperatives in the area with strong unity, which could provide a model. While there has been much documented success of the community management of natural resources in Mexico, one of the variables to this success is strong leadership and agreement amongst the community members (Klooster & Masera, 2000).

Ejido Governance Structure and Environmental Awareness Programs

One of the monitors belongs to an Ejido – a communally owned land tenure system in Mexico. The style of governance varies, but generally there is a council of Ejido delegates that convene to make decisions for members on their land-use and natural resources (Klooster & Masera, 2000). During our initial interview the monitor described how the Ejido put their land into a conservation easement with Pronatura. He mentioned that it took a while for people to agree but that the community, "slowly came around." He explained that the people belonging to his Ejido were changing, "every year they are becoming more environmentally aware. I think it's because of the governments programs." The Secretaría de Medio Ambiente y Recursos Naturales (SERMANAT) currently have 'Environmental Promoter" programs where they train individuals in a community how to educate people on recycling, conserving water, the importance of natural resources and proper disposal of trash. This monitor was part of this program and therefore an active environmental participant in his Ejido.

To demonstrate his Ejidos increasing interest in conservation he described a story where he was working with some of his fellow community members on a coffee parcel and had brought his binoculars along. He began to demonstrate to others how to identify birds and he said, "everyone thought it was interesting and wanted to use the binoculars." Furthermore, this monitor decided to present at his monthly Ejido meeting what he had been working on with us – the mobile data collection and why it was important. In a run-in with this monitors family they mentioned that because of the presentation the community now understands what that monitor was doing, saw the utility of the technology and were interested in the results. The Ejido's social structure: monthly meetings, their participation in government environmental programs, designation of land tenure as communal, are all conducive to creating a positive social influence for the acceptance and encouragement of community monitoring, and if they are supportive of monitoring that provides compatibility in the use of the mobile system for monitoring. With over 80% of Mexico's closed canopy forests residing in the hands of communally owned land (Klooster & Masera, 2000), the results of our study hold significant implications for the rest of Mexico in regards to implementing this mobile system for their forest monitoring needs.

While the monitor perceived his Ejido as becoming more supportive of environmental initiatives there was an additional important issue raised during his mobile data collection experience. During his independent monitoring he discovered that a member of his Ejido was committing a bad conservation practice and he asked us during our check-in whether he should report it using the observation form on the Android. Our response was that the data belonged to him and would only be shared with those who he wanted to share it with, but this illustrated a previously neglected possibility: The implementation of a mobile monitoring system could either promote positive conservation practices by the raised accountability within the community that the mobile system provides or it could generate tension and animosity among the community if members felt they were being judged for their land use practices that were not in line with the monitoring conservation goals. In summary, it appears as if the Ejido's positive participation in conservation (conservation easement, reaction to monitors presentation on data collection) warrants for an easy acceptance of the act of community monitoring, but as for the adoption of the technology for monitoring there wasn't enough evidence to determine their perspectives.

Peer Monitor Network

A positive social influence on the adoption of the mobile system is the presence of a "Peer Monitoring Network" nurtured by the Pronatura avian monitoring program. The monitors spent a week training together for the program, participated in the program due to a personal interest, and have periodic meetings to discuss the monitoring protocol. One monitor expressed his delight in a trip he and his fellow peer monitors had planned to go camp in the center of El Triunfo to look for the Quetzal. During a test of the mobile system with other monitors present their interactions suggested that they reinforce or validate each other's reason for monitoring. This was demonstrated in the healthy competition for remembering the scientific names of the birds and the monitor who was testing the phone was encouraging the others to see how it worked (Figure 19).

This camaraderie amongst the monitors could create the needed technical support that may not be currently accessible from Pronatura or CYN. If one of the more technologically advanced monitors was thoroughly trained in the use of the mobile system, due to this peer network, that monitor could diffuse and provide technical support to the additional monitors interested in using the system. Additionally an apprenticeship program could be initiated to help continue and reinforce the training and learning amongst the monitors while simultaneously including new interested members. This could ensure a consistent review of the data collection protocol to the "teacher" monitors and a cost-effective way to train and involve new "apprentice" monitors.

Noted by one of the monitors and in a response from the CYN survey was the prospect of including youth in the data collection. During one of our sampling events a monitor brought his daughter along who learned the ODK application and how to collect data after two samples (Figure 19). The monitors daughter also helped show us how to use the family computer, demonstrating her technical knowledge. Encouraging the peer network to facilitate the exchange between the technical expertise of the youth and the traditional ecological knowledge of the older generation could help older generations, fearful for the lack of facilitating conditions, feel comfortable with using a new technology system (CIGA UNAM 2011).

Figure 19 Left, an example of the monitors gathered before an avian point count sample. Right, a monitor demonstrates to his daughter how to use the phones on a sampling event.

Perceived Ease of Use

Perceived ease of use is defined as the degree to which a person believes learning the new technology will be easy (Davis, 1989). If a person perceives the technology as difficult and complex to learn they are less likely to tackle the issue of learning it where as if they see it as easy (and with facilitating conditions like guidance and tech support) they are more likely to consider making the effort to learn the system.

All four monitors stated during their interviews that the initial learning of the phones might be difficult but with our assistance and practice it would be easy to learn. Since we did not teach the monitors the system beyond data collection they generally perceived the mobile data collection as simple and without complexity. We had an opportunity to demonstrate to two monitors how to upload the data and they observed, but they didn't ask any questions. After demonstrating the upload I asked whether they would want to learn this part of the process and they noted that, "I have no experience with computers, learning them would be difficult, but I want to learn everything."

An employee at Pronatura noted that he thought teaching community members how to use the technology would be incredibly difficult because, "some are illiterate and most have very little education." Additionally, the delegates of Comon Yaj Noptic defined one of the barriers to this system as, "learning how to use it." However one of the CYN member-monitors, who was observed using Google Earth and sharing photos of birds with fellow community members frequently, had a significant amount of motivation to learn how to use the rest of the system and an assumed capacity to do so. This motivation could suggest that he didn't perceive the next stems of the system as incredibly difficult or complex. In summary, the monitors perceived the mobile data collection as easy to use, but the cooperative and Pronatura perceived it as a potential barrier.

Perceived Usefulness

Perceived Usefulness is described in the literature as the degree to which a person believes that the use of a technology will help them succeed in their job (Davis 1989). The definition has been expanded to include whether a person thinks the results of using the technology are valuable, extrinsic motivation, and how useful the technology is compared to their previous method, relative advantage (Venkatash, 2003). In the context of mobile community monitoring it could be defined as whether an individual thinks the phone is more useful than the paper data collection form.

Two of the monitors in their interviews defined the relative advantage of the mobile phones compared to the paper forms as reducing the time it takes to enter the data into the computer. A monitor noted that currently it takes him about 10 days to enter one months worth of the seven monitors data into the computer.

However, an important observation was the change in the perception of the advantage of the mobile system after the monitors used the phones. Three out of the five monitors noted during the wrap-up presentation that the phone was better, but the paper was sufficient. One commented that, "the paper [data collection method] and the phone are the same, they are both important." Another described the use of the phone as, "the same but better" yet afterwards during our check-in he noted, "the phone is useful, but I still will always use my notebook as a backup." After one monitor collected several DBH measurements during an above ground biomass sampling event he lost half of the data on the phone. In his frustration he claimed that maybe the paper data collection is better because there isn't the threat of data loss quite like there is with technology.

Yet in contrast, one monitor kept the opinion that the phone, "seems to be better [than paper]" and during data collection kept mentioning how much he liked the phone. Quantitatively, there was no measured difference in how long it took to enter one species of bird into the phone as opposed to the paper (Table 14, following page). The results are mixed in that it appeared that the monitors saw the utility in using the phones to collect data but considered the paper forms to be equivalent, or even necessary for a backup while using the phones.

Table 14 Recorded time by monitor to enter one bird species into phone and paper forms

Method	Time Trial 1	Time Trial 2	Time Trial 3	Average
Phone	00:34	00:38	00:30	00:36
Paper	00:15	00:35	00:30	00:26

Conclusion

We rated each variable as having a positive or negative influence on the adoption of the mobile system. In total there was more positive variables for the adoption of the mobile system than negative. However, like most matters, each variable contains some positive influence and some negative influence, it just depends on the degree to which one variable appears more positive than negative or vice versa. Below are some suggestions for improving the positive influence or reducing the negative influence of these variables:

- We noted that while the phone might not be perceived as useful due to the degree of uncertainty that comes with technology use, the mobile monitoring system could still include a protocol where the individual uses the paper form to collect the data and then in a more secure setting manual transfers the data to the phone, still providing the usefulness in uploading the data to the computer and for quick analysis.
- While there was a perceived lack of resources from Pronatura by the monitors, Pronatura was responsible for generating the Peer Monitor Network, which provides a positive social influence and potential facilitating conditions for the adoption of the mobile system.
- There should be an emphasis among the Ejido to include all members in the process behind the monitoring program and in the decision of the monitoring targets in order to remove possibility of tension from accountability or database insecurity.

This case study indicates that the key components to a successful community monitoring program (Table 15, following page) are evident in the region: users can learn the technology quickly, have motivation for the monitoring targets and an interest in participating in further use of the mobile system. However to really ensure the adoption and use of the system there needs to be a strong emphasis in fortifying the organizational support (CONANP, CYN, Pronatura) to manage the data collection and provide ongoing technical expertise. In our synergistic conclusion we discuss these recommendations in further detail.

Table 15 Summary of some of the key components needed for a successful CBNRM program

Author/Source	Key Component
CIGA UNAM 2011	Facilitating presence of an NGO or local government authorities to train members of the community, manage the program and provide technical expertise – most important in the beginning of a program
Blom 2010	Motivation or relevance of monitoring target for community; can be due to personal interest or economic
Jeffrey-Coker, F., Basinger, M. & Modi, V., 2010	Protocol for database management and data transfer
Blom 2010	Involving community at all stages of the monitoring process

CHAPTER 4: Synergistic Conclusions

Table 16 is a summary of the technical and social barriers for implementing a community based mobile monitoring system that we observed during our pilot.

Table 16 A summary of the technical and social barriers and opportunities

	Opportunities	Barriers
Technical	• The collection of multiple types of data during the same sampling event allows for dynamic data collection and encourages more sampling • Costs associated with sampling was low compared to the time and effort spent (see Table 9) • Low amounts of sampling effort, resulted in large amounts of data collected • Variables for a PES (rare species, forest cover, biomass estimation, forest utility) can be collected and visualized for potential verification through a mobile monitoring system • ODK features, like predictive text and hints allow for streamlined data collection and cater to various levels of monitoring experience	• Digital data collection system based on an advanced operating system can have unknown failures, resulting in frustration and data loss • Form creation and data collection may be prohibitive because of current language options • Current state of technology requires high level of computer aptitude and prevents complete bottom-up use of the system • For the system to be completely community driven it will depend on increased computer competence capacity or a development effort that makes the entire system easier to use

Social	• The system could align economic motivations with conservation goals by integrating ecological monitoring questions into the internal control practices of coffee cooperatives • The visualization capabilities could enhance competitiveness in the market by promoting conservation coffee production practices • The phone equipment and ODK application can be learned by people with varying levels of technological experience • A point of entry for integrating the mobile system is within the current monitoring infrastructure in the area, the CONANP park guard program and the Pronatura avian bird monitoring program • The transparency and ease of use in the system can provide autonomy to private land owners in the process for verification in PES programs	• There is a lack of organizational support for database management • There is no current economic incentive for monitors to conduct ecological monitoring – this could be addressed by coming PES schemes • The unclear expectations on monitoring targets coupled with the ability to have multiple forms in one device – led to less data collection than desired. • The ability for community volunteers and park guards to use the analysis tools has yet to be tested

Local/Regional Recommendations

Aligning Economic Incentives with Conservation Goals

Comon Yaj Noptic and other regional cooperatives are looking for ways to improve their internal control and production processes. In the survey with CYN they noted the numerous benefits to automating internal control: increasing marketability, reducing clutter, facilitating quicker turnarounds for compensation, reducing time for data collection and transfer and simply better organization. CYN recognizes these benefits and are economically motivated to change their paper internal control forms into an electronic format given access to the resources to do so. The mobile system we tested for automating CYN's internal control, ODK, is simultaneously being tested by another pilot program with a different cooperative in the region. This demonstrates that the technology is coming, and coffee cooperatives are interested in using it.

However, there is still a need in the region for baseline natural resource data (Water Services PES, REDD+) and monitoring of biodiversity in El Triunfo. A promising area of overlap could be integrating conservation questions into the internal control process. For example, if at the end of each internal control form there was a question asking for evidence of rare species or illegal logging then the 148 partners in the CYN cooperative that are interviewed each year could provide 148 samples of important forest resource data. Furthermore, our study demonstrated the use of the voice record option at the end of a form as a type of ecological diary by the monitors. A voice record prompt at the end of the internal control form could provide a space for coffee producers to share observations on water levels, fruiting time for various plants and severity of landslides that can aid in understanding the effects of climate change. Using mobile technology to align economic and conservation goals has been documented with much success (Banks & Burge, 2004) and there appears to be great potential of aligning the two in Comon Yaj Noptic and the surrounding region due to the nature of the economic activity (shade-grown coffee) and its location within the buffer zone of REBETRI and the current monitoring programs run by Pronatura and CONANP.

Data Management Needs

The region currently lacks a central figure in dedicating time and resources for data management. Ideally the community would be the collectors and managers of their own data but previous pilots in the region by AMBIO have proven that the role of an NGO in facilitating the initial process and providing continuing support is vital. It appears that the most suited for this responsibility would be Pronatura but from the interviews with employees it seems that their human and physical resources are currently at their limit, leaving little to fulfill this role. Therefore it will be vital to identify a local organization, possibly the vocational technical school that is located on CYN property, to serve as the facilitator for database management.

Potential for Tourism/Biological Research Station

Both the owner of Pakayal and Arroyo Negro expressed interest in building capacity on their properties for ecotourism or a biological research station. There is a growing interest in the developed world for “science tourism” which basically means assisting in scientific studies as an impetus for visiting exotic locations. While there are many critics who cite negative cultural effects of ecotourism on local communities (Buckley, 2009), it is an industry that is growing quickly and there are emerging standards that protect the rights of communities involved in the industry (The International Ecotourism Society, 2012). The potentiality of the mobile monitoring system and the popularity of El Triunfo amongst birders coupled with the interest by the private land owners could create conditions for an added attraction of science tourism while simultaneously generating the needed regional baseline data for REBITRI.

An example of this is in Pronaturas development of the community monitoring program in the Biosphere Reserve of La Encrucijada to include ecotourism development. The monitors, in addition to collecting avian point count data, are learning how to guide tourists on avian biodiversity tours. The mobile system could be used to increase the attractiveness of such a tour in that participants could also help collect the data as they go on their tour, participating in “science” tourism. The tours could help generate the much-needed financial resources to invest in the back-end of the mobile data collection system.

Verification for Coming Regional and National PES Schemes

The onset of potential regional water funds and the developing Carbon Coffee certification by CERTIMEX, "Certificadora Mexicana de Productos y Procesos Ecológicos," are an example of economic motivation for organizations such as the AC "Coffee Producers for the Promotion of Café" (established by one of the monitors and the director of CYN) and Arroyo Negro to cultivate this mobile system as a way to verify and visualize their conservation practices in order to mobilize them to receive compensation, quite like the Suruí in the Brazilian Amazon. This mobile system would cut initial costs for paying outside or external verifiers for their services, and as the owner of Arroyo Negro stated, "this system can liberate us from the coffee conservation mafia." Additionally, if they are well primed to receive benefits from these payments for ecosystem services then they can demonstrate to surrounding land owners the benefits in the system and encourage their participation. This type of technology diffusion process has the potential to generate financial resources because the more adopters/interested parties in this mobile system would mean more investment of human and social capital from local conservation organizations that could spark relationships with the mobile technology industry (Banks & Burge, 2004).

Nurturing Environmental Motivation for Monitoring, not Economic

In developed countries monitoring, or "citizen science," is perceived as a leisure activity, something to enrich the experience for an outdoor enthusiast or engage youth in science education (Van Der Burg, Dann, & Dirkx, 2009). In developing countries the idea of "citizens" collecting data, more commonly referred to as participatory monitoring, has focused on the idea of community monitoring for the management of their natural resources (Danielsen, 2003, 2010 & 2011). In the literature there is little mention of the motivations for community participants being grounded in leisure or out of passion for conservation and the natural world, instead the literature tends to focus more on natural resource management needs of forest communities in developing countries. Our experience with all four monitors, and the other monitors within the Pronatura monitoring program, demonstrated that they participate in this program mainly because they enjoy the activity, find it fun and care about protecting the habitat for the birds. Another student who studied the monitor motivations in the program discovered that their participation in the monitoring program helped change their perspective towards caring for the environment (Personal Communication, J. Lowry, 2012).

One of the monitors was extremely apprehensive about accepting our compensation for his participation in testing the mobile system. He anecdotally explained and demonstrated in his survey response that he was so grateful to have been part of this project and the opportunity to enhance his passion for conservation and avian monitoring skills. Additionally, in four out of the five individual sampling events he conducted his response on the audio record feature had some mention of improving environmental awareness or the importance of nature in his life and his communities. This situation raises a question, are we neglecting the environmental/leisure motivations of community volunteers in developing countries? Is the environmental or conservation oriented motivation behind participation in community monitoring something to nurture rather than the economic motivation provided by PES programs? In an interview with an employee from AMBIO he emphasized the need to culture an environmental ethic from the communities for conducting carbon sequestration monitoring – he said without it the project becomes unsustainable because the community is usually disappointed in the compensation for their carbon and is unlikely to keep up the conservation of the forested land. A strong focus on involving the community monitors in the use of the mobile system for data collection based on their conservation and environmental interest might prove more sustainable than focusing on the potential benefits from PES programs that are still in their beginning stages of development.

National Recommendation

Community Monitoring of Natural Resources Infrastructure

Comisión Nacional Forestal (CONAFOR), has had a lot of success in a community monitoring method called a Participatory Geographical Information System (GIS) where community members are trained in mapping their resources using varying degrees of GIS (Conference Proceedings 2011; Peters-Guarin, 2011). Additionally, CONAFOR is responsible for making Mexico a leader in establishing and maintaining successful community based monitoring programs for natural resources management (Klooster & Masera, 2000). The Comisión Natural de Áreas Naturales Protegidas (CONANP) which is responsible for the management of protected areas also plays an important role in training park guards to monitor various mammals and plant species. Both organizations have the capacity and experience and are positioned to diffuse information on community monitoring of natural resources in forested areas across Mexico. Therefore, if CONANP and CONAFOR employees were trained in the mobile data collection system they could serve as a supportive organizational infrastructure in for the 80% of communities that live on forested lands in Mexico (Klooster & Masera, 2000). The existing training infrastructure within CONANP and CONAFOR is a key leverage point to promote the use of this mobile system for quicker, more transparent and efficient data collection by park guards and communities to create long-term, national scale baselines for natural resources.

International Recommendations

Google's presence at the COP 16 and the focus on mobile tools at the community monitoring workshop in Mexico City suggest, among other sources, that large scale conservation initiatives are carefully considering community based environmental data collection. The linkage between the local and the global through data collection could be a great compromise between locally-based and decentralized approaches. Instead of a debate that attempts to demonstrate the success of either method, mobile-based community monitoring systems have the potential to facilitate a collaborative approach that addresses the barriers and opportunities of each. Experts who doubt the data quality of community collected data can verify and spot check point-referenced data with links to evidence of the methodology used. Pro-rural groups like Via Campesina who reject large scale PES programs due to concerns over equal benefit sharing can use public databases to correct error, ground truth projections and create more transparency of payment processes. As McAfee (2010) notes, PES might be rejected outright in a country like Mexico because of its neo-liberal approach (or at least its framing as a neo liberal approach), but data transparency and granting communities more agency is undoubtedly a move towards compromise if it is at all possible. Over the past decade, the project level approach to forest conservation has fallen in favor to the top down approach like the REDD+ program (Blom, 2010). The inclusion of communities for data collection in the MRV process is means to re-apply the benefits of community based natural resource management without losing the management and oversight of the regional and national level approach.

Beyond MRV for REDD+, PES programs all face the challenge of finding evidence for return on investment of a conservation decision that uses economic valuation techniques.

Programs like watershed payments, conservation cost share initiatives and conservation easements all maintain a need to demonstrate that management decisions based on a PES framework have economic and conservation value. In a watershed payment scheme, payments to upstream users to prevent environmental degradation are designed to prevent costly downstream issues like erosion, increased flood risk and dam sedimentation. To make such an investment, policy makers and local stakeholders need to see evidence that payments upstream are having an effect. What is needed is beyond a single pre and post analysis of the watershed, but consistent monitoring of indicators that demonstrate improved ecosystem services. Community monitoring of these indicators has the potential to fill this role while increasing local capacity and improving transparency of the payment scheme. An excellent example of the monitoring challenge of PES programs is the Natural Capital Project's ecosystem service decision-making tool called Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST). InVEST uses available data to estimate biophysical provision and economic values of ecosystem services in a GIS then demonstrate the costs of making land use decisions for invested stakeholders. However, after a decision maker uses the tool to make a land-use decision, the basic estimates are only an estimate of return on investment. InVEST, a mapping tool, is well designed to accept near-real time point-referenced data from the areas involved in InVEST, but is only beginning to examine what methods it might use to monitor the provision if ecosystem services in areas that the platform has been used. The cost associated of long term monitoring in areas that use the InVEST tool is likely to be prohibitive, but might be overcome with low-cost community methods. The path ahead is developing relevant indicators for community members that are sensible to collect, but also have real meaning to analyze environmental health.

A large-scale pilot PES program that bases its data collection on community monitoring is therefore recommended by our research. The tools we have tested present a structure for verifiable near real time data collection. As Daily *et al*. (2009) says: it is time to deliver on PES programs by committing to making decisions based on an ecosystem services model. Financial incentives have the potential to address many of the resources and motivation concerns of community monitoring we discussed in our research. A true test of the system requires an innovative conservation organization to demonstrate that they trust in the agency of a community to monitor and manage their own natural resources. Skutch (2011) commented that if the true end goal of the REDD+ program is changes in conservation practices, why are we proposing to pay for carbon instead of management? A PES program that finances community based monitoring does not just pay for inanimate ecosystem services, it pays for people to engage with their natural resources, improve their environmental decision making and hopefully encourage a positive attitude towards conservation.

Conservation Leadership Program Synergies and Next Steps

The Sierra Madre of Chiapas is likely to attract more Conservation Leadership Program thesis work in the future. We recommend that the result of the projects concerning La Suiza Micro Watershed and risk assessment, Sierra Madre PES, evaluation of monitor capacities and our own research be viewed together to suggest future CLP research. From our standpoint, a community monitoring element could be developed within the La Suiza Micro Watershed risk assessment methodology. In the La Suiza study, a CLP student with a handheld GPS and community input captured "Points of Community Interest" to map key factors of vulnerability. Based on our research, a replicable and sustainable vulnerability assessment could be carried out by community members of communities like La Suiza, giving them more agency in the risk assessment process and perhaps more awareness of the root factors of risk. Additionally, as the potential for a Tuxtla Gutierrez water fund becomes a reality, organizations like FONCET must consider how they will monitor the flow of ecosystem services as well as safeguards like equal benefit sharing. The thesis work conducted by CLP students working on Chiapas PES programs creates baseline for future research and the addition of community monitored variables to improve the efficiency of an emerging regional waterfund. Finally, a student thesis effort that focused on Pronatura's avian community monitoring program suggested that the monitoring of natural resources might enhance environmental awareness. Considering these projects there is great potential for future CLP students to examine these synergistic themes in the Sierra Madre.

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APPENDIX I

Complete structure of all data collection forms

In addition to the questions that the users view, all devices upon completion of the form record the start and end time, submission date and time to the server and a unique identifier for each data collection event.

Rare Species Observations Question Structure	ODK Data type
Geographic location	Android internal GPS Records latitude, longitude, altitude and accuracy
Latitude	Numeric entry option for non service areas
Longitude	Numeric entry option for non service areas
Altitude	Numeric entry option for non service areas
Name of observer	Text
Date	Widget that displays date and user verifies
Image of evidence	Android internal camera activates
Rare Species Select One	Select from a list of rare species with common and species name
Non listed species	Text
Sex	Select one Male, Female or Unknown
Observer experience	Record Audio Function

Forest Utility Question Structure	ODK Data type
Geographic location	Android internal GPS Records latitude, longitude, altitude and accuracy
Latitude	Numeric entry option for non service areas
Longitude	Numeric entry option for non service areas
Altitude	Numeric entry option for non service areas

Name of observer	Text
Date	Widget that displays date and user verifies
Route Name	Text
Time Start	Numeric with restrictions for valid times
Time end	Numeric with restrictions for valid times
Number of cut logs observed	Numeric
Observer experience	Record audio function

Avian Point Count Question Structure	ODK Data type
Geographic location	Android internal GPS – Records latitude, longitude, altitude and accuracy
Latitude	Numeric entry option for non service areas
Longitude	Numeric entry option for non service areas
Altitude	Numeric entry option for non service areas
Date	Widget that displays date and user verifies
Locality	Text
Transect name or code	Text
Begin looped group (Avian Data)	Looped groups allow for repeat observation until user exits the group
Point number	Select one (1-11)
Time observations begin at point	Numeric with restrictions for valid times
Specie observed	Select one with predictive text referenced against internal list of all birds of the Triunfo
Number of individuals	Numeric
Sex	Select one Male, Female or Unknown
Habitat	Select one from list of habitat types provided by Pronatura
Forage type	Text

Tree species	Text
Vegetation strata	Select one Low Medium or High
Observation by audio or visual	Select multiple A or V or Both
End looped group (Avian Data)	User can exit or continue to make repeat avian observations
Rare species observed during transect	Text
Number of cut logs observed	Numeric
Observer experience	Record audio function

Above Ground Biomass Question Structure	ODK Data type
Geographic location	Android internal GPS – Records latitude, longitude, altitude and accuracy
Latitude	Numeric entry option for non service areas
Longitude	Numeric entry option for non service areas
Altitude	Numeric entry option for non service areas
Name of observer	Text
Date	Widget that displays date and user verifies
Plot Habitat	Select one from list of habitat types provided by Pronatura
Plot Status	Select multiple with human land use options like logging and agriculture
Begin looped group (tree data)	Looped groups allow for repeat observation until user exits the group
Tree Name	Select one with predictive text referenced against internal list of tree species of the Sierra Madre
Diameter at Breast Height	Numeric
End looped group (tree data)	Numeric

General Observation Question Structure	ODK Data type
Geographic location	Android internal GPS – Records latitude, longitude, altitude and accuracy
Latitude	Numeric entry option for non service areas
Longitude	Numeric entry option for non service areas
Altitude	Numeric entry option for non service areas
Name of observer	Text
Date	Widget that displays date and user verifies
Image	Activates internal Android camera
Notes	Text
Observer experience	Record audio function

Land Cover Question Structure	ODK Data type
Geographic location	Android internal GPS – Records latitude, longitude, altitude and accuracy
Latitude	Numeric entry option for non service areas
Longitude	Numeric entry option for non service areas
Altitude	Numeric entry option for non service areas
Name of observer	Text
Date	Widget that displays date and user verifies
Locality	Text
Habitat	Select one from habitat types provided by Pronatura
Height of Canopy	Numeric
Image North	Activates internal Android camera
Image East	Activates internal Android camera
Image South	Activates internal Android camera
Image West	Activates internal Android camera

Observer experience	Record audio function

Internal Control of Coffee Operations Question Structure	**ODK Data type**
Geographic location	Android internal GPS – Records latitude, longitude, altitude and accuracy
Latitude	Numeric entry option for non service areas
Longitude	Numeric entry option for non service areas
Altitude	Numeric entry option for non service areas
Name of Promoter	Text
Date	Widget that displays date and user verifies
Name of Producer	Text
Community	Text
Ranch name	Text
Hectares of land in coffee	Numeric
Hectares in land in conservation	Numeric
Presence or absence of non coffee crops	Select one – Y or N
Types of other crops	Select one – names of regional crops with skip logic applied. This question only appears if the previous answer is Y
Presence or absence of natural water source	Select one – Y or N
Presence or absence of coffee nursery	Select one – Y or N
Image of the nursery	Activates Android internal camera skip logic applied. This question only appears if the previous answer is Y
Number of plants in the nursery	Numeric skip logic applied. This question only appears if nursery was indicated as Y
Cultivar of coffee that dominates the	Select one – Arabia, Burboun or Marago skip logic

nursery	applied. This question only appears if the previous answer is Y
Presence or absence of "beneficio humedo"	Select one – Y or N
Presence or absence of coffee patio	Select one – Y or N skip logic applied. This question only appears if the previous answer is Y
Presence or absence of coffee grinder	Select one – Y or N skip logic applied. This question only appears if the beneficio answer is Y
Presence or absence of coffee fermentation tanks	Select one – Y or N skip logic applied. This question only appears if the beneficio answer is Y
Condition of coffee patio	Text skip logic applied. This question only appears if patio presence = Y
Image of coffee patio	Activates Android internal camera skip logic applied. This question only appears if patio presence = Y
Condition of coffee grinder	Text skip logic applied. This question only appears if grinder presence = Y
Image of coffee grinder	Activates Android internal camera skip logic applied. This question only appears if grinder presence = Y
Condition of fermentation tanks	Text skip logic applied. This question only appears if fermentation presence = Y
Image of fermentation tanks	Activates Android internal camera skip logic applied. This question only appears if fermentation presence = Y
Conservation practices	Select multiple with complete list of certification conservation compliance like live fences and protected streams
Image of coffee producer and family	Activates internal Android camera
Observer experience	Record audio function

APPENDIX II

This appendix contains the surveys administered, two graphs demonstrating frequency of certain categories found in the responses to the CYN surveys and when, where and for how long qualitative data was collected.

Copies of surveys handed out to monitors and delegates of CYN.

¡Gracias por su participación en nuestro proyecto! Agradecemos mucho su interés y su gran esfuerzo ayudándonos. Para finalizar nuestro proyecto nos gustaría colectar información sobre como mejorar el sistema móvil de recolección de datos. Este cuestionario es solo para conocer como les fue al usarlo y que sugerencias tienen para el futuro.

Por favor, responda a las preguntas siguientes:

1. *¿En promedio, Cuantos días usas el aparato?*

2. *Por favor, circula uno según su habilidad.*

Sus habilidades de monitoreo:
Principiante Intermedio Avanzado

Sus habilidades de tecnología:
Principiante Intermedio Avanzado

3. *Por favor clasifique que tan fácil o difícil que era usar el aparato:*
1 - Más Fácil, 2 - Fácil, 3 - Normal, 4 - Difícil, 5 - Más Difícil

Nombre de Formato	**Más fácil ——— Mas difícil**					**No Uso**	**Comentarios**
Uso de Suelo	1	2	3	4	5		
Especies Raras	1	2	3	4	5		
Control Interno	1	2	3	4	5		
Anillos	1	2	3	4	5		
Gremios	1	2	3	4	5		
Utilidad de Bosque	1	2	3	4	5		
Observación	1	2	3	4	5		

Monitor Survey Page 1

4. Por favor, marca que tan útil eran:

1- Muy Útil, 2 - Útil, 3 - Neutral, 4 - Un Poco Útil, 5 - No Útil

Nombre de Formato	Muy Útil				No Útil	No Uso	Comentarios
Uso de Suelo	1	2	3	4	5		
Especies Raras	1	2	3	4	5		
Control Interno	1	2	3	4	5		
Anfibios	1	2	3	4	5		
Orquídeas	1	2	3	4	5		
Utilidad de Bosque	1	2	3	4	5		
Observación	1	2	3	4	5		

5. Por favor, marca que acción es mas fácil:

1- Más Fácil, 2 - Fácil, 3 - Neutral, 4 - Difícil, 5 - Más Difícil

Acción de Aprendizaje	Más fácil ——— Más difícil					Comentarios
Operaciones básicas (apagando, cargando)	1	2	3	4	5	
Guardando formatos	1	2	3	4	5	
Navegando el menú	1	2	3	4	5	
Usando el teclado	1	2	3	4	5	
Encontrando formatos	1	2	3	4	5	
Entrando datos en el aparato	1	2	3	4	5	
Instrucciones en los formatos	1	2	3	4	5	
Otra Cosa: ____________	1	2	3	4	5	

Monitor Survey Page 2

6. ¿Habían otras cosas que querías monitorear? ¿Qué eran?

7. ¿Cómo piensas que este sistema podría impactar tu comunidad u organización?

8. ¿Cuáles serían las barreras para implementar este sistema?

9. ¿Cómo se podrían superar estas barreras?

10. ¿Cuáles son las oportunidades que brinda este sistema?

11. Otros pensamientos

Nombre: ______

Fecha de Nacimiento: ______

Nivel de Educación: ______

Trabajo: ______

Monitor Survey Page 3


Nombre:

Fecha de Nacimiento:

Título:

¿Cómo piensas que este sistema podría impactar la cooperativa?

¿Cómo piensas que este sistema podría afectar la comunidad de Nueva Paraíso?

¿Cuales son las barreras para implementar este sistema?

¿Cómo se podrían superar estas barreras?

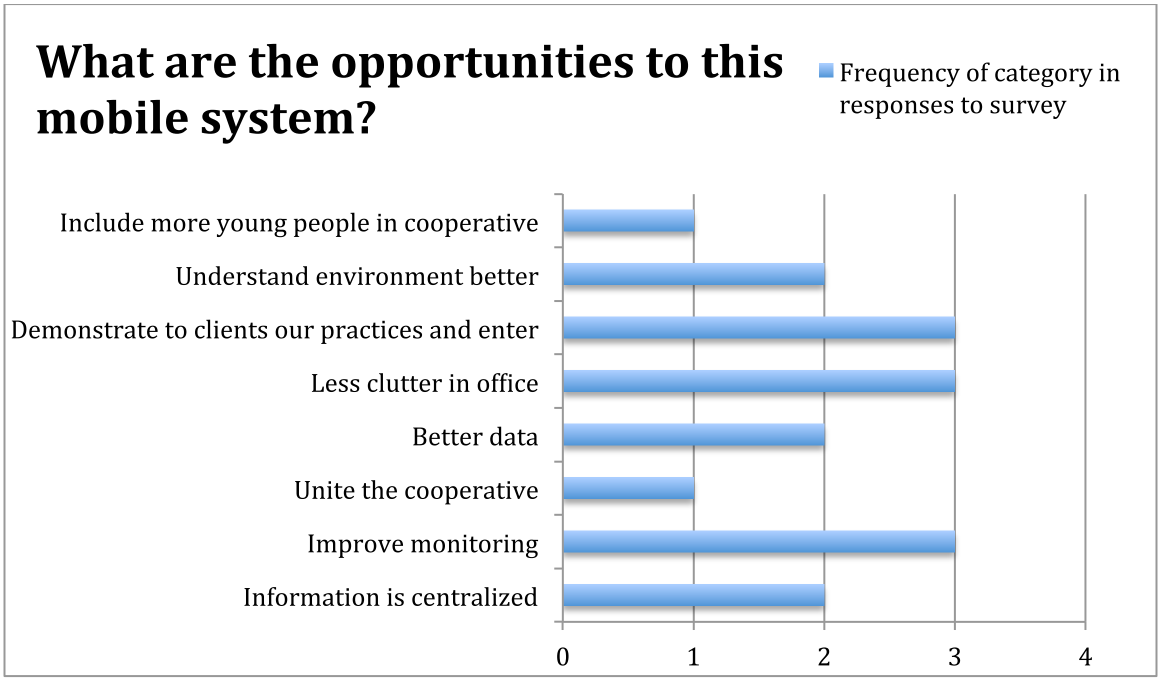
¿Cuales son las oportunidades que brindaría usar este sistema?

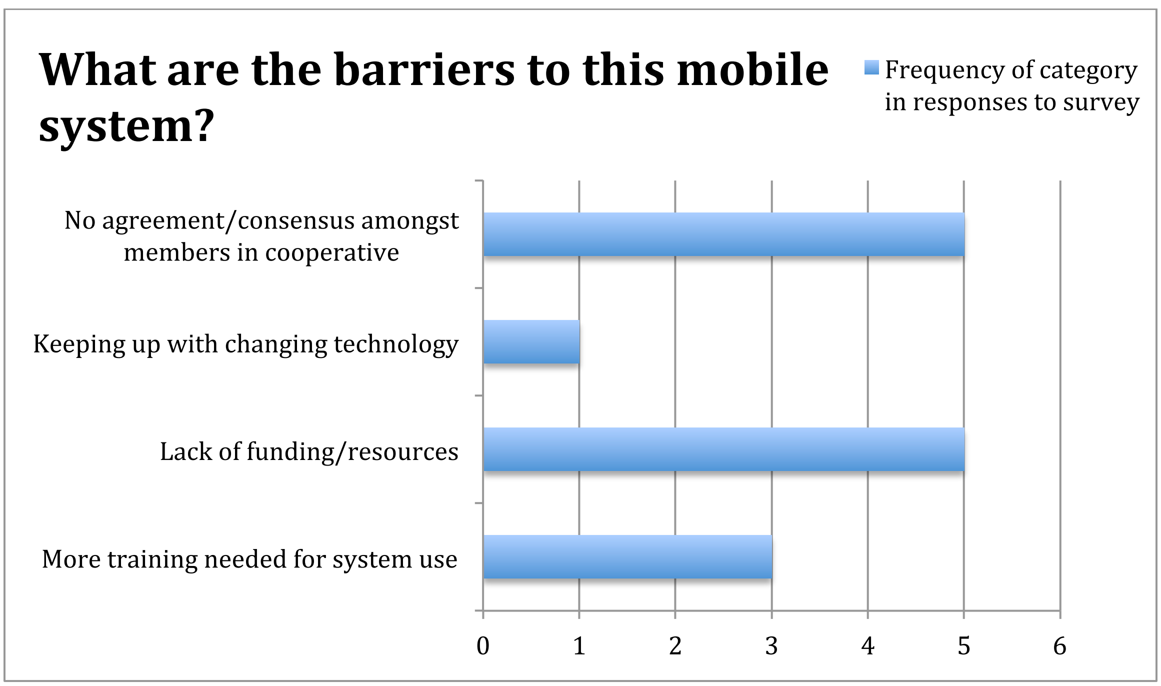
¿Otros Comentarios?

CYN Survey

Responses to CYN survey

Responses coded and tallied from the questions on the CYN survey





Interviews conducted for quantitative analysis: date, interviewee position and focus

Date	Interviewee	Focus
7/22, 8/10	Ambio employees	Previous training experience in mobile community monitoring
9/15		
10/21 – 10/29	Community Volunteer Monitor	Learning Curve, Opportunities and Barriers
10/21		
10/29		
10/22		
10/25 – 10/26		
12/14	Owner of Arroyo Negro	Opportunities and Barriers
12/13	Pronatura employees	Community Monitoring Program
10/05		

Dates and location of field notes, participant observation and digital recording data collection

Date	Total Time (days/hour)	Activity	Where
9/4/11	½ day	Determining Monitoring Targets and Introduction to Monitors	Office of Comon Yaj Noptic (CYN)
9/15 – 9/16/11	2 days	"Linking Community Monitoring to MRV in REDD+ Conference"	Mexico City
10/6/11	1 hour	Indoor training with Pedro Pablo	San Cristobal
10/19 –	3 days	Training Rene and Victor	Pakayal, Cuxtepec

10/21/11			
10/22/11	2 hours	Meeting with Jose Luis of CYN to determine Internal Control forms	CYN office
10/24 – 10/28/11	4 days	Training Pedro Pablo	Arroyo Negro
10/29/11	1 hour	Check-in with Victor on data collection	CYN office
11/3/11	1 hour	Training Miguel	CYN office
11/4/11	½ day	Field training with Miguel	Nueva Paraiso
11/5 – 11/6	2 days	Establishing transects with Rene/Check-in	Pakayal, Cuxtepec
11/7 – 11/8	1 day	Field data collection with Miguel for internal control	San Francisco, Cuxtepec
11/8 – 11/13	5 days	Above ground biomass data collection	Arroyo Negro
11/18	1 hour	Check-in with Victor	Moxquivil, San Cristobal
12/12/11	1 hour	Presentation to Efrain from Arroyo Negro. Administer PP survey.	San Cristobal
12/13/11	3 hours	Presentation to CYN of results/Recollection of phones. Administer surveys to CYN and Monitors.	CYN office