# EVALUATION OF CONAFOR'S PAYMENTS FOR HYDROLOGICAL SERVICES PROGRAM, 2003-2010

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*EVALUACIÓN DEL PROGRAMA DE PAGO POR SERVICIOS HIDROLÓGICOS (PSA-H) DE CONAFOR, 2003-2010*

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[1] The authors appear in alphabetical order. +,#, * indicate, respectively: University of Wisconsin, Amherst College, and Duke University. We are most grateful to CONAFOR for their generous sharing of time, expertise and data, without which we would not have been able to complete even day one of this project. We thank our survey coordinator, Rodolfo Rubio Salas and our team of encuestadores for their perseverance and time in the field. We are also grateful to Ipsita Agarwal, Rachel Baker, Selene Castillo, Leah Fine, Adam Medoff, David Ortega Flores, Mara Munoz Quetzalli Jane Rice, Caroline Stedman, Melissa Sullivan, and Alejandro Sucre for their research assistance, and to Pedro Camilo Alcantara for the processing of NDVI which is used as an important outcome in the third part of this report. We are especially grateful to the International Initiative for Impact Evaluation (3ie) and the National Science Foundation #1061852 for financial support.

# Contents

# RESUMEN EJECUTIVO

Este documento resume los resultados actuales de la evaluación del Programa de Pagos por Servicios Hidrológicos de México de 2003-2010 realizado por investigadores de la Universidad de Wisconsin-Madison, la Universidad de Duke, y la Universidad de Amherst. Damos las gracias a la Comisión Nacional Forestal de México (CONAFOR) por el intercambio generoso de datos y tiempo contribuidos al proyecto. Nuestra evaluación trata de comprender los impactos ambientales y socioeconómicos del programa, con el objetivo de extraer las lecciones aprendidas e identificar las posibilidades de mejoras a futuro. Esta sección resume nuestras principales conclusiones y recomendaciones.

**Parte I: Visión general del programa y análisis de la participación**

*Resultados:* El análisis de los criterios de selección del programa y las características de los terrenos inscritos sugiere que el programa ha cumplido con el doble objetivo de destinar fondos a áreas con prioridad ecológica y social. En concreto:

- Los terrenos inscritos entre 2004 y 2010 tuvieron un riesgo similar de deforestación, mayor prioridad hidrológica, y un grado de marginalidad similar a todos los terrenos forestales en el país.

- La focalización en terrenos con mayor riesgo de deforestación y nivel de marginación ha mejorado sustancialmente a través del tiempo debido a los cambios en las reglas del programa y de las zonas elegibles. Todo esto ha llevado a a la selección de áreas con mayor riesgo y pobreza dentro del grupo de aplicantes.

***Recomendaciones:*** Una de las maneras posibles de aumentar el impacto ecológico del programa sería seleccionar propiedades con riesgo de deforestación aún mayor, ya que el riesgo promedio de deforestación entre las propiedades inscritas se mantiene un poco por debajo de la media nacional de todos los terrenos forestales. Dos maneras posibles de hacer esto sería focalizar aún más en función de las múltiples características que determinan la deforestación evitada (además de los números de riesgo INE) o elevar los montos de pago.

**Parte II: Impactos socioeconómicos**

*Resultados:* La comparación de las respuestas de las encuestas hechas a beneficiarios y solicitantes rechazados del programa en 2008 sugiere impactos socioeconómicos generalmente neutrales o positivos del programa. En concreto:

*Impactos en riqueza*

• Encontramos que, en promedio, todos los hogares están ganando en riqueza material a través del tiempo, pero el aumento de los activos de los beneficiarios no es significativamente más grande que lo de los no beneficiarios.

*Impactos en trabajo, producción y crédito*

• En general, el programa no ha afectado significativamente la producción agrícola o ganadera. La mayoría de los beneficiarios originalmente empleados en agricultura, ganadería o silvicultura siguen trabajando en esas categorías y los porcentajes globales de personas empleadas en cada sector son muy similares a través del tiempo.

• La producción de cultivos alimentarios, incluidos los cultivos básicos, no disminuye en promedio o muestra diferentes tendencias generales entre los beneficiarios y no beneficiarios, lo que sugiere que el programa no pone en peligro la seguridad alimentaria.

• Tanto los beneficiarios como no beneficiarios muestran intensificación de la agricultura y mayor valor de la producción agrícola por hectárea a través del tiempo. La prevalencia de desmonte de tierras para el cultivo no es significativamente diferente entre los beneficiarios y no beneficiarios.

• En general, las tendencias en la producción ganadera no son significativamente diferentes entre los hogares beneficiarios y no beneficiarios. No obstante, vemos un aumento en el número promedio de cabezas de ganado en beneficiarios que viven en terrenos comunales, lo que posiblemente indica un impacto positivo en los activos no reflejado en el análisis anterior. Los pequeños propietarios o propietarios privados muestran una disminución en la producción de ganado y en las tierras utilizadas para pastoreo, pero las tendencias fueron muy parecidas entre los beneficiarios y no beneficiarios.

• Con respecto a la inversión y el crédito, encontramos evidencia tentativa de que el programa podría haber mejorado el acceso al crédito para algunos hogares. Los pequeños propietarios beneficiarios del programa tienen menos probabilidad de

pedir crédito. Asimismo, vemos algún incremento en la producción de cultivos comerciales entre los hogares pobres que viven en propiedades comunales. Los hogares en comunidades beneficiarias que no estaban invirtiendo en nuevos cultivos o infraestructura ganadera al inicio del estudio son más propensos a invertir en el año 2011. El programa parece haber ayudado a las familias de ejidatarios, en comunidades donde los fondos del programa se distribuyeron como transferencias directas, y a pequeños propietarios a mantener a sus hijos en la escuela por más tiempo.

*Impactos en el manejo forestal*

• El programa definitivamente ha tenido un impacto positivo en el nivel y la calidad de manejo forestal implementado por los propietarios beneficiarios, lo cual probablemente mejore los servicios ecológicos proporcionados por su bosque.

• El programa ha incrementado la capacitación en el manejo forestal y las actividades dedicadas al manejo del bosque – esta formación puede tener beneficios a largo plazo que van más allá del programa.

• El programa ha aumentado significativamente el tiempo dedicado a actividades relacionadas con la prevención y lucha contra los incendios forestales, patrullaje contra la tala ilegal y la caza furtiva, control de plagas, y construcción de cercos para que el ganado no entre al bosque. El tiempo dedicado a este trabajo puede tener beneficios a largo plazo para la salud de los bosques.

• Las reglas que rigen el uso del bosque han aumentado a través del tiempo, pero los hogares en comunidades beneficiarias están ligeramente más inclinados que los no beneficiarios a sentir que su acceso al bosque es más difícil que en el pasado.

*Costos de solicitud e implementación*

• Los datos de la encuesta indican costos considerables para los solicitantes, tanto de la solicitud para el programa como la ejecución de actividades de manejo forestal.

• Los costos de solicitud son relativamente pequeños en comparación con los pagos totales, pero los costos de mano de obra adicional que se utiliza para la implementación de los planes de manejo forestal son grandes en comparación con los pagos totales.

*Beneficios percibidos del programa*

- Los beneficiarios del programa generalmente conocen el programa y tienen impresiones positivas acerca de los efectos percibidos del programa.

- La mayoría de los beneficiarios perciben que los beneficios principales del programa son mayor ingreso-empleo y apoyo a la conservación de los bosques.

- Una alta proporción tanto de los ejidos como de los pequeños propietarios beneficiarios informaron que les gustaría volver a inscribirse en el programa después de la terminación de sus 5 años de contrato.

- Los beneficiarios y no beneficiarios, por igual, son escépticos sobre la posibilidad de poder vender directamente servicios ambientales a los particulares cuando el programa termine.

***Recomendaciones:*** Aunque la falta de aumentos sustanciales en la producción o la inversión es algo decepcionante desde el punto de vista del alivio de la pobreza o generación de ingresos, es tranquilizador verificar que las tendencias son generalmente similares entre beneficiarios y no beneficiarios. Esto sugiere que el programa no ha tenido impactos negativos y que se ha preservado en gran medida las estrategias de vida que los hogares hubieran elegido en ausencia del programa. También es tranquilizador en cuanto a las preocupaciones acerca de posibles "fugas" de deforestación a áreas no inscritas de las propiedades (Alix-García et al. 2011), ya que no vemos una expansión adicional de la producción que requeriría la tala de áreas boscosas en otras partes de las mismas propiedades. Además, los resultados dan una indicación clara de que el programa ha tenido éxito promoviendo el aumento de las actividades de manejo forestal y la educación, y que las percepciones de los beneficiarios acerca de los impactos sociales y ecológicos del programa son positivas en general. Estos resultados sugieren que la continuación o ampliación del programa sin mayores cambios se justifica desde los puntos de vista ecológico y social.

Las elevadas estimaciones sobre los costos laborales relacionados a la implementación de actividades de manejo forestal indican que los costos de participación merecen más atención. Mientras que los pagos se justificaron inicialmente sobre la base del costo de oportunidad, los resultados de la encuesta sugieren que los mayores costos que afrontan los beneficiarios provienen del aumento en las necesidades de trabajo en el manejo forestal. Esto podría justificar un incrementoen el tamaño de los pagos en el futuro siempre que los presupuestos lo permitan. Las reglas del programa se modificaron en 2010 para reducir la cantidad y tipos de manejo forestal requeridospara así reducir los

costes laborales de los beneficiarios. En este sentido, será importante evaluar si estos cambios tuvieron éxito antes de decidir sobre nuevas medidas.

**Parte III: Impactos ambientales**

*Resultados:* La comparación de la cobertura forestal a través del tiempo entre los beneficiarios del programa y los solicitantes rechazados mediante datos satelitales de gruesa resolución indica que el programa ha reducido significativamente la pérdida de bosques en comparación con lo que se habría esperado en ausencia del programa.

*Impacto ambiental mediante NDVI*

- Tanto los beneficiarios como los no-beneficiarios demuestran bajadas en NDVI durante el período examinado. Sin embargo, el programa parece reducir la disminución del NDVI por alrededor de 62%. Esto sugiere que el programa reduce la deforestación y/o la degración en las áreas inscritas, pero no elimina completamente la tendencia negativa.
- Encontramos heterogeneidad significativa en los impactos sobre el NDVI, con más pérdida de NDVI evitada en los núcleos agrarios, en tierras de menor pendiente y más cercanas a las ciudades, y en los municipios menos marginados.

*Estimaciones de deforestación a escala fina*

*Resultados*: El análisis de Landsat tuvo varias dificultades debido a las complicaciones topográficas y fenológicas de México, además de lo que parece ser una caída de la tasa de deforestación en los últimos años (un promedio anual de menos del 0,3%). Estamos avanzando con el análisis Landsat utilizando una combinación de clasificación manual y Máquinas de Vectores Soporte.

***Recomendaciones:*** En conjunto, estos resultados indican un moderado impacto sobre la deforestación, con espacio para un mayor impacto a través de mejoras en la selección de propiedades beneficiarias. Sin embargo, teniendo en cuenta los resultados del impacto de esta sección, así como aquéllos presentados en la parte II,, nuestro análisis indica que las posibilidades de hacercambios en la orientación que puedan producir mayor deforestación evitada sin poner en peligro los objetivos sociales son limitadas. En concreto:

• Más deforestación evitada podría alcanzarse incrementando la focalizacióna tierras de alta calidad (por ejemplo, cerca de las zonas urbanas y con menor pendiente), pero estos cambios probablemente harían que el programa fuera menos progresivo en el sentido social.

• Más deforestación evitada también podría lograrse aumentando los pagos con el fin de inducir la inscripción de tierras con mayor riesgo de deforestación. Esto podría aumentar los impactos positivos sobre la marginación, pero implicaría pagos más elevados a un menor número de personas al menos que el presupuesto del programa también se expandiese.

• Nuestros resultados indican que una de las posibilidades de "ganar" en las dos dimensiones (deforestación y pobreza) es una mayor focalización de los pagos a los núcleos agrarios, que son más pobres en promedio y que también muestran mayores impactos de deforestación evitada. CONAFOR ya se ha movido en esta dirección y se recomienda mantener este cambio.

**Parte IV: Discusión de preguntas claves**

La sección final del informe se centra en las cuestiones planteadas por la CONAFOR en el transcurso del proyecto. Esta sección está aún en proceso de revisión, pero se resumen aquí los temas y resultados hasta la fecha.

*Monitoreo socioeconómico en el futuro*: Este análisis indica, con varios ejemplos, cómo una comparación sencilla del antes y el después entre las comunidades beneficiarias podría llevar a conclusiones erróneas. Cambios en el manejo forestal y los medios de vida son impulsados por una serie de factores que van más allá del programa. Esto destaca la importancia de recopilar información de un grupo de control, como ser los solicitantes rechazados, en cualquier análisis futuro que se haga sobre los impactos. Proponemos algunos posibles indicadores socioeconómicos y estrategias de muestreo para la supervisión.

*Monitoreo ambiental en el futuro:* Al igual que el monitoreo socio-económico, es útil incluir tanto los beneficiarios como los no beneficiarias. Sugerimos una muestra estratificada basada en la proporción de la superficie inscrita en diferentes tipos de bosques con el fin de obtener una mejor estimación de la tasa de deforestación en general.

*Costos de oportunidad y pagos actuales:* Consideramos las ganancias por hectárea bajo actividades agrícolas y ganaderas según tipo de bosque. Bajo la suposición que los costos se distribuyen en forma parecida por todos los tipos de bosque, concluimos que los mayores pagos actuales a los bosques mesófilos se justifican por las ganancias y crecimiento de ganancias mayores dentro de este tipo de bosque. Sin embargo, las ganancias parecen ser relativamente mayores en bosque coníferas comparados con las selvas, lo cual no es consistente con la esquema actual de pagos.

*Indice de selección y ponderación:* Observamos que los criterios de selección para el PSAH han cambiado significativamente a través del tiempo, por lo cual es difícil

establecer el impacto de muchos de los cambios que se ocurren simultáneamente y en años consecutivos. Los años reciente han visto la adición de un número significativo de criterios ambientales. Bajo la esquema actual, la importancia de ellos pesa mucho más que la de los criterios que tienen mayor correspondencia con las metas escritas del programa – alivio de la pobreza y la deforestación evitada. Este hecho puede disminuir la efectividad del programa. Sugerimos un esquema alternativo de ponderación que permite la adición de otros criterios sin comprometer las metas del programa.

## EXECUTIVE SUMMARY

This document summarizes current findings from an evaluation of Mexico's National Payments for Hydrological Services from 2003-2010 carried out by researchers at the University of Wisconsin-Madison, Duke University, and Amherst College. We thank the Mexican National Forestry Commission for generous sharing of data and time contributed to the project. Our evaluation seeks to understand the environmental and socioeconomic impacts of the program, with the goal of extracting lessons learned and identifying room for possible future improvement. This section summarizes our major findings and recommendations.

**Part I: Program overview and analysis of enrollment**

Findings: An analysis of program selection criteria and the characteristics of lands enrolled suggests the program has met the dual goals of targeting funds to areas of ecological and social priority. Specifically:

- Land enrolled between 2004 and 2010 had similar risk of deforestation, higher hydrological priority and similar degree of marginality to all forested lands in the country.
- Targeting to high deforestation risk and more marginalized areas has improved substantially over time due to changes in the program rules and the eligible zones resulting in the selection of higher risk and more poor recipients from within the applicant pool.

***Recommendations:*** One potential means of improving the ecological impact of the program would be to select properties with even higher risk of deforestation, as the average risk of deforestation among enrolled properties remains somewhat below the national average across all forested lands. Two possible ways to do this would be to target further on the basis of multiple characteristics which determine avoided deforestation (in addition to INE's risk numbers) or to raise the payment amounts.

**Part II: Socioeconomic impacts**

Findings: A comparison of household and community survey responses from 2008 beneficiaries and rejected applicants to the program suggests generally neutral or positive socioeconomic impacts of the program. Specifically:

*Wealth impacts*

- We find that all households on average are gaining in material wealth over time, but wealth increases for beneficiaries are not significantly larger than those for non-beneficiaries.

*Labor, production and credit impacts*

- Overall, the program has not significantly affected agriculture or livestock livelihoods. The majority of beneficiaries originally employed in agriculture, livestock or forestry remain employed in those categories and the overall percentages of people employed in each sector are very similar across time.
- Production of food crops, including staple crops, does not decrease on average or show different general trends between beneficiaries and non-beneficiaries, suggesting that the program does not compromise food security.
- Both beneficiaries and non-beneficiaries show intensification of agriculture and rising value per ha of production across time. Reported prevalence of land clearing for cultivation is also not significantly different across beneficiaries and non-beneficiaries.
- Livestock production trends are generally not significantly different between beneficiary and non-beneficiary households. We do however see an increase in the average number of livestock owned by beneficiary common property households, possibly indicating a positive impact on assets not captured by the previous analysis. Private property households overall showed decreases in livestock production and land used—but trends were very similar across beneficiaries and non-beneficiaries.
- With respect to investment and credit, we find tentative evidence that the program may have made credit more available for some households. There is less borrowing among private property beneficiaries and we see some increased production of cash crops among poor common property households. Common property households who were not investing in new crops or livestock infrastructure at baseline are more likely to invest in 2011 if they were beneficiaries. The program appears to have helped ejidatario households in which the program funds were distributed as lump-sum transfers and private property households to keep their children in school longer.

*Forest management impacts*

- The program has clearly had a positive impact on the level and type of forest management implemented by beneficiary landowners, which is likely to improve ecological services.
- The program has increased training in forest management and activities devoted to forest management--such skill training is likely to have long term benefits that extend beyond the program.
- The program has significantly increased the time spent in activities related to preventing and combating forest fires, patrolling against illegal logging

and poaching, pest control, and erecting fences to limit access by grazing animals. The time dedicated to this work is likely to have long term benefits for forest health.

- Rules governing forest use have increased over time, but households in beneficiary communities are only slightly more likely than households in non-beneficiary communities to feel that it is more difficult to access the forest than in the past.

*Application and implementation costs*

- Our survey data indicate considerable costs to applicants both from applying to the program and implementing forest management activities.
- Application costs are relatively small compared to the overall payments, but the full costs of additional labor used for implementation of forest management plans are large compared to overall payments.

*Perceived benefits of the program*

- Beneficiaries of the program were generally aware of the program and were positive about the perceived impacts of the program.
- Most beneficiaries perceive the main benefits of the program to be extra income/employment and support for forest conservation.
- A high proportion of both ejidos and private property beneficiaries reported that they would like to reenroll in the program after the their 5-year contract is finished.
- Beneficiaries and non-beneficiaries alike are skeptical of the potential to directly sell ecosystem services to private parties when the program ends.

***Recommendations:*** Although the lack of substantial increases in production or investment is somewhat disappointing from a poverty alleviation/ income generation standpoint, it is reassuring that trends are generally similar between beneficiaries and non-beneficiaries. This suggests the program has not had negative impacts and has largely preserved livelihood strategies that would have been chosen in the absence of the program. It is also reassuring in terms of possible concerns about substitution slippage or "leakage" of deforestation to non-enrolled areas of the property (Alix-Garcia et al. 2011), since we don't see additional expansion of production that might require new clearing on other parts of the same properties. In addition, the results do give a clear indication that the program has been successful in promoting increased forest management activities and education and that beneficiary perceptions of the social and ecological impacts of the program are generally positive. These results suggest that continuation or expansion of the program without major changes is justified from both ecological and social standpoints.

The large estimates for labor costs involved in implementing forest management activities suggest that the costs of participation deserve more attention. While payments were originally justified on the basis of opportunity cost, the survey results suggest that the greatest costs to beneficiaries are due to the labor requirements of increased forest management. This may justify an increase in the size of payments in the future if budgets will support them. Program rules were changed in 2010 to decrease the amount and types of forest management required in order to decrease beneficiary's labor costs, so it would also be important to evaluate whether these changes were successful before deciding on further action.

**Part III: Environmental impacts**

Findings: A comparison of forest cover across time between program beneficiaries and rejected applicants using coarse-resolution satellite data suggests that the program has significantly reduced forest loss compared to what would have been expected in the absence of the program.

*Environmental Impact using NDVI*

- Both enrolled and unenrolled properties show decreases in NDVI over the period examined. However the program appears to reduce the temporal change in NDVI by around 62%. This suggests that the program either reduces deforestation or degradation in enrolled properties, although it does not seem to entirely eliminate the overall downward NDVI trend.
- We find significant heterogeneity in avoided NDVI loss impacts, with larger impacts in communally held lands, on land of lower slope and closer to cities, and in less poor municipalities.

*Fine scale deforestation estimates*

Findings: The Landsat analysis has been fraught with difficulties due to the topographical and phenological complications of Mexico, in addition to what appears to be a falling rate of deforestation in recent years (an average annual rate of less than .3%). We are moving forward with the Landsat analysis using a combination of manual classification and Support Vector Machines.

***Recommendations:*** Together, these results indicate a moderate avoided deforestation impact, with room for stronger impacts through improvements in targeting of payments. However, considering the impact results from this section as well as Part II above, our analysis indicates only limited potential for changes in targeting that could produce more avoided deforestation without compromising social goals. Specifically:

- More avoided deforestation could be gained by additional targeting to high quality lands (for instance near urban areas and with lower slope) but these changes would likely make the program less progressive.
- More avoided deforestation might also be achieved by raising payments in order to induce enrollment of land at a higher risk of deforestation. This could increase positive wealth impacts but would mean higher payments to fewer individuals unless the program budget is also expanded.
- Our results indicate that one possibility for a "win-win" on both dimensions is additional targeting of payments to communally-owned properties, which are poorer on average and also show higher avoided deforestation impacts. CONAFOR has already moved in this direction and we recommend keeping this change.

**Part IV: Discussion of key questions**

The final section of the report focuses on questions brought up by CONAFOR during the course of the project. This section is still being revised, but we summarize here the topics and findings to date.

*Future socio-economic monitoring:* This analysis indicates in many examples how a simple before-after comparison among beneficiary communities could lead to incorrect conclusions. Changes in forest management and livelihoods are driven by a host of factors outside of the program. This underscores the importance of collecting information for a control group such as rejected applicants in any future analysis of impacts. We propose some possible socio-economic indicators and sampling strategies for monitoring.

*Future environmental monitoring:* Similarly to the socio-economic monitoring, it is useful to include both beneficiary and non-beneficiary communities in the monitoring sample. We suggest a sample stratified based on the proportion of area enrolled in different forest types in order to obtain a better estimate of the overall deforestation rate.

*Current payment scheme and opportunity costs:* We consider the revenues per hectare in both agricultural and cattle-raising activities across the different forest types in our sample. Under the assumption that costs are distributed in similar ways across forest types, the current relatively high payments to mixed mesophytic forests are justifiable, though earnings appear to be much higher in coniferous regions relative to rainforest, which is in contrast with the current payment scheme

*Selection index and weighting:* We observe that the selection criteria for the PSAH have changed significantly over time, and note that it is difficult to establish the impact of so many changes happening both simultaneously and in consecutive years. Recent years have seen the addition of a significant number of environmental criteria. Under the current selection system, the importance of these far outweigh those given to criteria that correspond more closely to the stated goals of the program – poverty alleviation and avoided deforestation. This could undermine program effectiveness. We suggest an alternative weighting scheme that allows for the continued addition of individual targeting criterion without compromising program goals.

# INTRODUCTION

**Purpose**

This project evaluates the socioeconomic and environmental impacts of CONAFOR's National Payments for Hydrological Services Program (PSAH) between 2004-2010.[2] The program is often promoted in policy circles as a model for large-scale incentive programs that can both slow deforestation and reduce poverty, yet few rigorous studies have been done to evaluate its impacts. Mexico's program represents one of the first efforts to implement a national-scale payments for environmental services (PES) program in a middle-income country. The program compensates landowners in exchange for land use practices that are thought to enhance the production of environmental services. Between 2003 and 2011, approximately 2.7 million hectares of forestland were entered into the program. More than US$450 million of federal funds have been distributed to 3,979 communal or smallholder private property participants, making the program one of the largest in the world (CONAFOR 2012).

Mexico's PSAH program has the potential to serve as a key model for the design of incentive-based mechanisms to ameliorate global environmental degradation and rural poverty. It is one of the first large-scale PES programs to take place in a region with significant rates of deforestation. Lessons from this program could play an important role in the design of global REDD (reduced emissions from deforestation and degradation) agreements currently being negotiated under the UN Framework Convention on Climate Change (UNFCCC 2007). In 2008, the World Bank's Forest Carbon Fund cited the success of the PES program as an important factor for selecting Mexico as one of only fourteen countries slated to develop national REDD schemes, and the PES division of CONAFOR was designated to play a significant role in developing the program. Because of its scope and scale, a rigorous evaluation of lessons learned from Mexico's national program could also have substantial benefits for the global community. This report presents preliminary results from a multi-year, interdisciplinary evaluation of the PSAH. The broad goals of the evaluation are as follows:

**1) Environmental effectiveness:** The primary goal of the PSAH program is to maintain forest cover in order to enhance hydrological services. Our evaluation therefore aims to answer the following questions:

[2] The official title of the program has changed due to incorporation in CONAFOR's "Pro-Arbol" initiatives although the basic structure has been retained. Here we refer to the program throughout by its original title.

a. Did property owners who received payments reduce their rates of deforestation on enrolled properties (compared to what would have happened if they had not received payments)?
b. How does the program's effectiveness in preventing deforestation vary according to the socioeconomic and geographic characteristics of the recipients, such as degree of initial levels of poverty, distance to markets, and private vs. communal land ownership?
c. Did the program cause significant displacement, or "leakage" of deforestation from enrolled properties to nearby un-enrolled properties, possibly undermining environmental benefits?

**2) Socioeconomic impacts:** Although the primary goal of the program is environmental, PES programs have been promoted in Mexico and elsewhere for their potential to improve incomes for rural communities, particularly for the rural poor. We therefore aim to answer:

a. Are there significant socioeconomic benefits of the program for in participating communities o+r households?
b. What are the major costs of program participation at the household and community levels (including opportunity costs, forest management costs, and transaction costs)?
c. How do program socioeconomic impacts vary according to such factors as region, initial levels of poverty, distance to markets, private vs. communal land ownership, and institutional capacity?
d. In what ways has the PSAH program changed local forest resource management planning and behavior of individuals and local institutions? Is there evidence that participation in the program has increased institutional capacity to manage local environmental services?
e. Are the observed socioeconomic and behavioral impacts likely to be sustained after payments end?

**3) Policy implications:** Mexico's program has the potential to serve as an important model for global efforts to scale up PES programs generally and as part of REDD initiatives. Our project therefore also seeks to respond to the following questions:

a. What does Mexico's experience suggest about meeting dual goals of environmental and socioeconomic benefits? Can PES improve the livelihoods of the rural poor while enhancing environmental services?
b. What does the observed heterogeneity of socioeconomic and environmental impacts suggest about possible targeting strategies? Do

we see important tradeoffs from increased targeting on land quality, initial levels of poverty, or land tenure type?

c. What lessons can we draw from Mexico's experience for the design of international REDD agreements? For example, what do the costs of transacting with small landholders and of monitoring and evaluation tell us about the feasibility of other REDD programs? What do measured "leakage" amounts suggest about the the advantages of national versus regionally targeted programs?

**Data used**

This report intends to provide preliminary answers to many of these questions, based on our assessment of data currently available. To date, we have constructed and analyzed the following datasets:

- National-level program data: property boundaries, program status, poverty indices and geographic characteristics of applicants to the PSAH program between 2003-2010.
- Household and community survey data: a national survey of more than 1250 beneficiary and non-beneficiary households and common property leaders. Covers 233 properties from the 2008 applicant pool. Survey conducted in 2011; contains retrospective questions from 2007.
- Forest cover data: average annual dry season NDVI from coarse resolution (MODIS 250m) satellite data between 2003-2011

Three data compilation and analysis efforts are ongoing:

- Case study data: Continued full analysis of transcripts from detailed interviews in 18 properties.
- Price data: The collection of monthly price data from 40-50 sites across Mexico
- Forest cover data: The processing of higher-resolution (Landsat 30m) satellite images from 14 Landsat footprints between 2000-2011.
- Heterogeneity in impacts: This report focuses mainly on the average impacts of the program. Future analysis will continue to explore possible differential impact by region, access to markets, etc.

The incompleteness of the current data limits our ability to answer questions regarding slippage and precise avoided deforestation impacts, although the data on hand provides significant insight into the impact of the program on both environmental and social outcomes.

**Evaluation methodology**

The entire research project is conducted within a program evaluation framework. Evaluation of the PSAH presents the standard identification problem: proper attribution of impacts depends on a comparison between how program recipients

would behave with or without the program, but one cannot observe how recipients would have behaved had they not received payments. A reasonable first approach to such a problem is to make a simple comparison of how recipients behaved before and after payments. However, observed changes in recipient behavior might be attributed to other time-varying circumstances (migration, weather, economic growth, etc). It is therefore important to also account for overall trends across time. For this reason, our evaluation estimates impacts by comparing differences in behavior between recipients and rejected applicants across time. The rejected applicants are a reasonable "counterfactual" or "control" group--they started off in similar circumstances to the recipients group and likely experienced the same time-varying circumstances, but did not receive PSAH payments. A key advantage of using controls drawn from the applicant pool is that the owners of these parcels have demonstrated their desire to enroll in the program, revealing that their expected participation costs are sufficiently low to motivate application. However, there are multiple characteristics which may still differ between accepted and rejected beneficiaries. To create the best possible control groups, we matched each beneficiary property with a non-beneficiary property which was from the same geographic region and the same tenure type and which had similar observable baseline characteristics.[3] Our estimates are then based on comparisons between matched beneficiary and non-beneficiary properties.

**Outline**

This report is broadly divided into four sections: the first presents an overview of programmatic changes and enrollment over time, the second, socio-economic impacts, the third, environmental impact, and the fourth conclusions and recommendations. Naturally, however, Parts I-III of the document interact significantly. The fourth represents an attempt to synthesize and to respond to questions put to us directly by CONAFOR during the course of the project.

[3] The details of the matching strategy for the survey sample and spatial analysis are given in their respective sections.

# PART I: PROGRAM OVERVIEW AND ANALYSIS OF ENROLLMENT

Despite the increasing global popularity of Payments for Ecosystem Services, researchers and policymakers have raised concerns about whether these programs can effectively protect forests and whether they can help the poor. In this section, we describe the basic structure of CONAFOR's hydrological services program and assess whether program targeting has been effective in selecting high risk forested areas and in promoting social goals. Specifically, we ask:

- What were the main components of program targeting and how did these change over time?
- Did the program succeed in enrolling ecologically significant areas?
- Did the program succeed in ensuring enrollment by marginalized households?
- How did changes in program rules change the composition of applicants and participants across time?

This background is useful for understanding the avoided deforestation results (Part III, section 1), as well as providing context for the impacts on socio-economic outcomes (Part II).

## Section 1: Program Requirements and Overall Enrollment

**Basic structure of the program**

Mexico's program of Payments for Hydrological Services grants five-year renewable contracts to both individual and communal landowners. Landowners may enroll a portion of their property and must maintain existing forest cover within the enrolled parcel, but can make changes to land cover in other parts of their property. Verification of forest cover is made by satellite image analysis or ground visits. Landowners are removed from the program if CONAFOR finds deforestation due to conversion to agriculture or pasture within the enrolled area. Payments are reduced if forest is lost due to natural causes such as fire or pests (Muñoz-Piña et al. 2008). Mexico's PSAH program goals include "maintaining forest functions that provide environmental services" and "compensating land owners for the environmental services provided by their forest lands" (CONAFOR 2012). Starting in 2006, program goals were modified to include poverty alleviation in addition to environmental services (Shapiro and Castillo 2012).

**Methods of analysis**

Criteria for the selection of areas to enroll in the program have changed several times since 2003. To categorize these changes, we reviewed annually published

rules of operation released by CONAFOR from 2003 to 2011. To understand what types of land were enrolled in the program, we constructed three samples of randomly selected points: 1) Points within enrolled PSAH properties; 2) Points within all forest areas across Mexico, as defined by INEGI's Series III vegetation layer; and 3) Points within rejected PSAH applicant properties. This enables us to assess how representative the PSAH is of the universe of forested land in Mexico. Shapefiles of enrolled and rejected PSAH program areas for 2004-2010 and databases of program information were provided by CONAFOR. Forest type classifications were created from the INEGI Series III land use layer from 2002. Shapefiles used to create variables were provided by or sourced from INEGI, CONAGUA, INE, and CONABIO.

**Selection criteria**

Table 1 summarizes the enrollment criterion over time from 2003-2011. In addition to these criteria, properties enrolled in the PSAH program must be within eligible zones as determined by CONAFOR; these zones expanded considerably between 2004 and 2009, but are currently being prioritized and downsized (Figure 1). Prior to 2006, the primary criteria for selection were being located within an eligible zone and having the minimum percentage of forest cover. In the first three years of the program, total land area in the eligible zones was relatively small, requiring that enrolled areas be upstream from urban areas of >5,000 and be located on an overexploited aquifer. Given the high demand for the program and evolving priorities, in 2006 multiple social and environmental selection criteria (e.g. degree of marginalization, female applicant, existing forest management plan, etc.) were added to refine the selection process. Applicants to the program were assigned points based on several criteria (Table 1). In the same year, the selection criteria for the eligible zones were also updated. Between 2006 and 2011, further selection parameters were added according to lessons learned and shifts in program mandates and priorities.

**Table 1: Selection criteria for PSAH program participants, 2003-2011, from the yearly program rules released by CONAFOR.**

* indicates a required criterion; •indicates an enrollment priority

| **Geographic Selection Criteria** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** |
|---|---|---|---|---|---|---|---|---|---|
| Within a Protected Natural Area | | | | • | • | • | • | • | • |
| Within zones related to water provision for urban centers with population >5,000 or within boundaries of CONAFOR priority mountains | * | * | * | • | • | • | • | • | |
| Within an area of high surface water scarcity | | | | • | • | • | • | • | • |
| Located in an overexploited aquifer | * | * | * | • | • | • | • | • | • |
| Within area of high risk of deforestation as classified by INE | | | | • | • | • | • | • | • |
| Area contains high biomass density determined by ECOSUR | | | | | | | • | • | • |
| Area has low rate of anthropogenic soil degradation | | | | | | | • | • | • |
| In a watershed where there are others with local payments for environmental services | | | | | | | | • | • |
| **Participant Selection Criteria** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** |
| No active legal battle over enrolled land | * | * | * | * | * | * | * | * | * |
| Not enrolled in any other CONAFOR PSA programs | | | | * | * | * | * | * | * |
| Priority to applicants with land of highest % forest cover | • | • | • | • | • | • | • | • | • |
| Applicant presents a forest management plan at time of application | | | | • | • | • | • | • | • |
| Applicants in municipality with majority indigenous population | | | | • | • | • | • | • | • |
| Applicants from marginalized areas defined by CONAPO | | | | • | • | • | • | • | • |
| Applicant is a woman | | | | | | • | • | • | • |
| Applicant presents a pending contract with an ecosystem service buyer | | | | • | • | • | • | • | |
| Applicant submits with other owners whose lands are adjacent | | | | | • | • | • | • | |
| **Land Requirements** | | | | | | | | | |
| Land area | 50-4000 ha | | | 20-3000 ha | | | 100-200 ha per individual; 200-3000 ha per community | | |
| Forest cover | 80% | | | 50% | | | | | |

**Figure 1: PSAH eligible zones, 2004-2009**

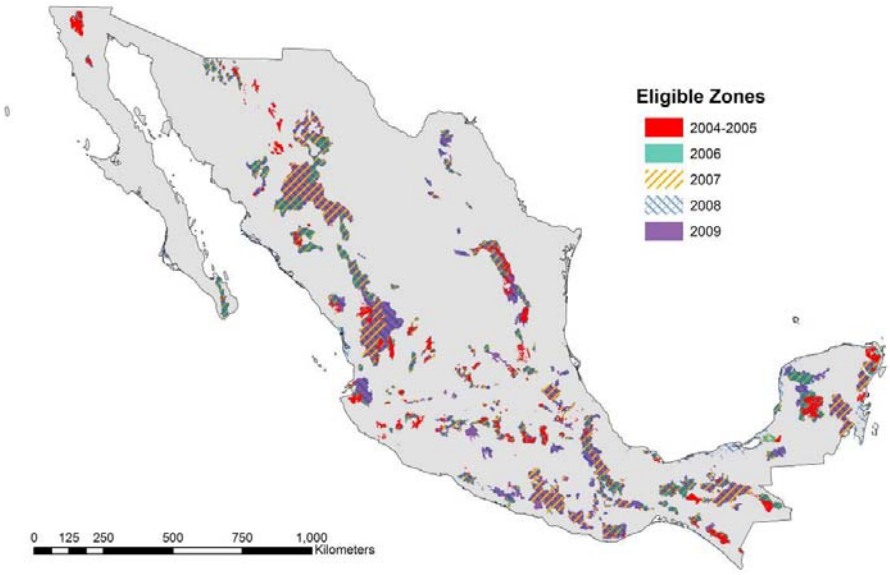


Table 2 shows the total number of properties and area enrolled in the program across time as well as the number of rejected applicants and the area that they proposed to enroll.

**Table 2: Total number of properties and land area enrolled in the PSAH program, 2003-2011, as indicated by yearly databases from CONAFOR.**

| Year | Number Enrolled | Area Enrolled (ha) | 5-Year Payments ($ MXN) | Number Rejected | Area Rejected (ha) |
|---|---|---|---|---|---|
| 2003 | 271 | 126817.97 | 191999999.98 | | |
| 2004 | 352 | 178676.17 | 288000000.00 | 209 | 256153.9139 |
| 2005 | 257 | 338045.15 | 515235160.43 | 226 | 212401.6118 |
| 2006 | 241 | 127015.76 | 204002584.94 | 380 | 492151.0063 |
| 2007 | 816 | 545576.96 | 925890661.30 | 889 | 878131.8602 |
| 2008 | 727 | 324154.77 | 662811103.64 | 2032 | 985468.0117 |
| 2009 | 410 | 320196.09 | 675478056.55 | 925 | 634332.5348 |
| 2010 | 688 | 508979.23 | 1116221417.27 | 1410 | 1196186.697 |
| 2011 | 217 | 195043.99 | 422569218.81 | n/a | n/a |
| **Totals** | 3979 | 2664506.09 | 5002208202.92 | 6071 | 4654825.636 |

**Targeting for hydrological services and avoided deforestation**

Table 3 shows the mean values for multiple land characteristics of the enrolled properties, all forested lands in Mexico, and rejected applicant properties from 2004-2010. The statistics clearly indicate that CONAFOR has been successful in targeting to areas of particular environmental concern and with high demand for hydrologic services. Relative to all forested points, points within enrolled PSAH areas are more frequently located within overexploited aquifers, priority mountain areas, and protected natural areas. The mean surface water availability for PSAH points is .15 standard deviations lower than that for all forested points. In addition, PSAH points are on average located .15 standard deviations closer to localities with a population over 5,000, where demand for greater water availability and hydrologic services is likely higher (Table 3).

Means of these variables for the sample of points in areas that applied to the program but were rejected indicate that this successful targeting is occurring at two stages during the enrollment process: recruitment and selection. Rejected points are more frequently located within overexploited aquifers and protected natural areas than all forested points and have lower surface water availability, indicating that applicants to the PSAH program are already to some extent targeted on the basis of environmental criteria and demand for hydrologic services. Relative to rejected applicants, enrolled PSAH areas are even more frequently in environmental priority areas and have even lower surface water

availability, indicating that targeting succeeds during this phase of the enrollment process as well.

**Table 3: Summary statistics for random samples of points within enrolled PSAH areas, all forests, and rejected PSAH areas, including the normalized differences between enrolled PSAH points and rejected and all forested points. (Program data from 2004-2010.)**

| Variable | Mean for enrolled PSAH points (n=20037) | Mean for all forested points (n=44104) | Mean for all rejected points (n=26228) | Normalized difference (enrolled PSAH vs. all forested) | Normalized difference (enrolled PSAH vs. rejected PSAH) |
|---|---|---|---|---|---|
| Slope (grade) | 12.1 | 10.3 | 11.9 | 0.136 | 0.020 |
| Elevation (m) | 1500 | 1160 | 1480 | 0.260 | 0.015 |
| Surface Water Availability | 6.84 | 7.18 | 6.88 | -0.159 | -0.017 |
| Overexploited Aquifer | 0.156 | 0.074 | 0.114 | 0.183 | 0.088 |
| Km to loocality w/ Pop. > 5000 | 33.0 | 38.1 | 38.6 | -0.144 | -0.160 |
| Risk of Deforestation | 2.49 | 2.85 | 2.40 | -0.183 | 0.052 |
| Priority Mountain | 0.255 | 0.068 | 0.112 | 0.371 | 0.266 |
| Protected Natural Area | 0.142 | 0.071 | 0.080 | 0.164 | 0.139 |
| Municipal Poverty Index, 2000 | 0.264 | 0.239 | 0.251 | 0.017 | 0.008 |
| Majority Indigenous | 0.375 | 0.248 | 0.244 | 0.196 | 0.202 |
| Communally Held Property | 0.878 | 0.604 | 0.812 | 0.465 | 0.130 |

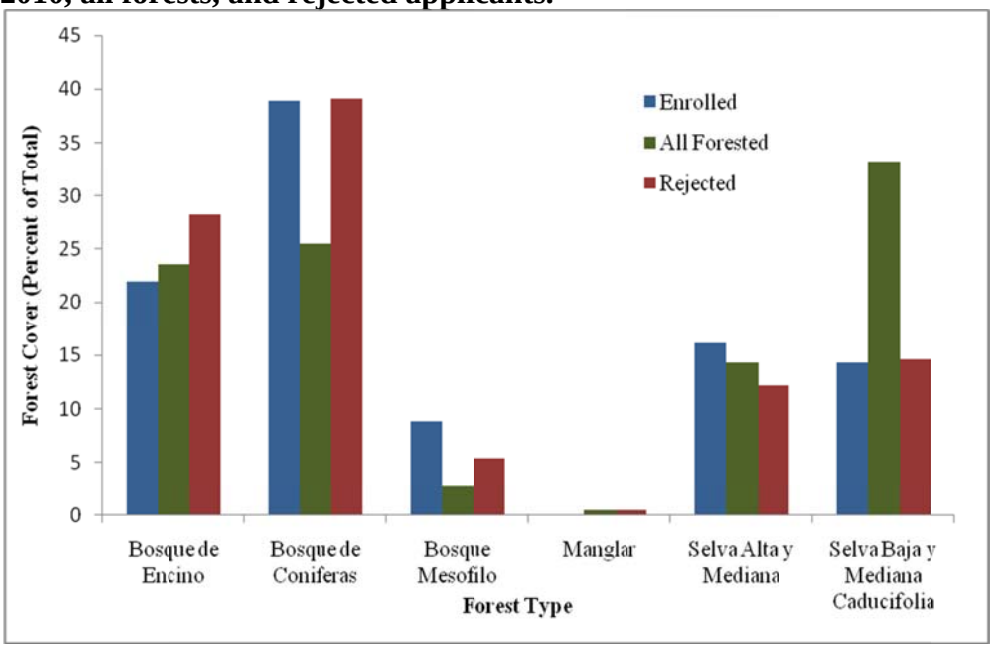
Targeting success on the basis of deforestation risk is less clear. The mean INE risk of deforestation for enrolled PSAH points is 2.49, significantly lower than the mean of 2.85 for all forested points. This value is, however, higher than the mean of 2.40 for rejected areas, suggesting that targeting on the basis of deforestation risk has been successful during the final selection of candidates. It is likely that some of the relatively low risk of deforestation for enrolled points may be due to poor recruitment in high-risk areas, possibly because payment rates are not currently high enough to attract the forest that has the highest risk of being converted to other uses. In addition, the INE classifications of risk of deforestation have only been used as a priority criterion for selection since 2006, so overall means for 2004-2010 obscure somewhat better targeting to high-risk areas in more recent years (as discussed in section 2). Due to the increased difficulty of converting land to agriculture, grazing, or forestry at higher slopes, land with higher slope and elevation may generally be at a lower risk of deforestation. Mean slope and elevation are higher for PSAH points than for both all forested points and points in rejected areas. It is possible that this selection of areas of higher slope and elevation may indicate a lack of good targeting to high-risk forests.

**Targeting by forest type**

Percentages by area of forest types enrolled in the PSAH program are generally comparable to the distribution of area for Mexico's forests as a whole, with bosque de encino (oak and pine forest) and bosque de coniferas (coniferous pine forest) composing the majority of both national forests and PSAH program areas (Figure 2). Relative to overall forests, the PSAH program has enrolled a greater percentage of bosque de coniferas and bosque mesofilo (cloud forest), and has under-enrolled manglar (mangroves) and selva baja y mediana caducifolia (low-altitude rainforest).

The initial two-tiered payment system for the PSAH program placed particular emphasis on enrolling parcels of cloud forest, due to the hydrologic importance of this forest type, and higher payments for cloud forest have persisted until the present (Munoz-Pina 2008). The apparent targeting to cloud forest (with 8.75% of enrolled land in cloud forest, vs. just 2.77% of all forested land) is an intentional and likely beneficial result of the PSAH program structure. It is possible that the over enrollment of coniferous pine forest may be explained by more extensive or effective recruiting in these areas; this possibility is supported by the similarly high percentage of coniferous forest in the rejected applicant pool.

**Figure 2: Distribution of forest types for PSAH enrolled properties 2004-2010, all forests, and rejected applicants.**




Forest type distributions were calculated using the INEGI Series III land use layer (circa 2002) and shapefiles of all PSAH applicants from 2004-2009. Forested areas from the land use layer were identified as one of six forest types based on the following classifications: **Bosque de Coniferas**: bosque de ayarin, bosque de cedro, bosque de oyamel, bosque de pino, bosque de pino/encino, bosque de tascate. **Bosque de Encino:** bosque de encino, bosque de encino/pino. **Bosque Mesofilo:** bosque mesofilo. **Selvas altas y medianas:** selva alta perennifolia, selva alta subperennifolia, selva mediana perennifolia, selva mediana subperenifolia. **Selva baja y mediana caducifolia:** selva mediana subcaducifolia, selva baja caducifolia, selva baja espinosa caducifolia, selva baja espinosa subperenifolia, selva baja perenifolia, selva baja subcaducifolia. The area of each of these forest type classifications within all program area polygons was calculated and compared to the overall land area of each type for the entire country.

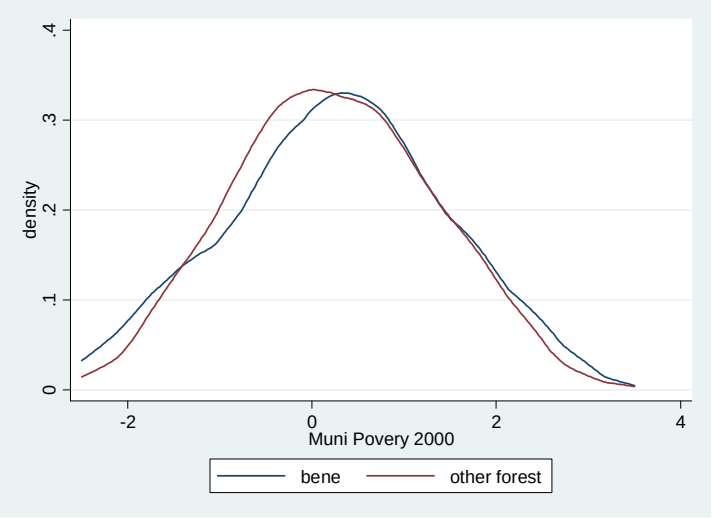
## Targeting for poverty

As indicators of poverty we consider two measures. First, we use CONAPO's municipal marginality index, which ranges from -2 to 2, with higher values indicating greater poverty. Second, we calculate the likelihood that a property has a majority indigenous population, as this metric tends to be highly correlated with poverty Mexico. Poverty levels for analyzed points were determined from the municipality-level index of marginalization for 2000, calculated and published by CONAPO. Analysis of points indicates successful targeting of funds to marginalized areas. The mean poverty index for PSAH points is 0.264, relative to 0.239 for all forested points and 0.251 for rejected points (a higher index indicates greater marginalization). Although the difference between PSAH points and all forested points is significant, the normalized difference of 0.017 suggests that the actual difference in this targeting is small. Figure 3 shows the distribution of municipality poverty index for enrolled properties compared to all other forested

points. We see that the distribution of beneficiary properties is generally shifted to the right, compared to all other forested points, illustrating successful recruitment of properties which are more poor into the program.

Points within PSAH areas are also significantly more frequently located in municipalities with a majority indigenous population than all forested points or rejected points, indicating successful targeting to these areas. Finally, PSAH points are more frequently on communally held land (*ejidos* or *comunidades*) than all or rejected points and on average households in common properties are less well-off than private landowners (Table 3).

**Figure 3: Municipal poverty of beneficiaries (2004-2009) versus all other forested areas.**




Marginality index by municipality from CONAPO (2000). Numbers correspond to poverty grades as follows: very low (<-1.3), low (-1.3 to -.7), medium (-.7 to -.1), high(-.1 to 1), very high( > 1). Data from points sample described above.

## Section 2: Policy Evolution and Enrollment in PSAH over time

This section analyzes shifts in the characteristics of the properties enrolled and the populations participating in the program over time. To better elucidate how the changes in program rules affected the types of properties enrolled, environmental and social variables were analyzed for accepted and rejected areas for each year 2004-2010 and characteristics of the eligible zones were compared across time.

**Changes in selection among recipients**

Mean values of a variety of indicators are summarized for all applicant properties in Table 4, which also includes the differences in mean values for accepted and rejected areas. The table shows significant changes in emphasis towards the selection of poorer properties and properties with higher risk of deforestation, both in the average trend and in the selection among applicants.

The average values of the marginality index for enrolled properties from 2004-2006 range from -0.329 to -0.121, and the likelihood of an enrolled property being located in a majority indigenous population during these years ranges from 0.125 to 0.185. 2007 marks a sudden shift in these social measures of targeting. Between 2006 and 2007, the mean marginality index for enrolled properties rises from -0.301 to 0.322; it then declines steadily to its 2010 value of 0.140. It is also important to note that the *difference* in marginality indices of accepted and rejected properties increases over time. This suggests that CONAFOR has tended, over time, to choose the poorer applicants from the pool. At the same time, the proportion of enrolled properties within majority indigenous municipalities rises from 0.139 to 0.427 before subsequently declining to 0.342. As with the marginality index, the difference in the probability of indigenousness between accepted and rejected properties increases over time, indicating greater selectivity of these types of properties within the applicant pool.

Concurrent with this apparent shift towards increased targeting to marginalized areas, targeting on the basis of deforestation risk also increases. We note that risk of deforestation among enrolled properties generally increases over time, from an average of 2.241 in 2004 to 2.747 in 2009 and with the largest increase between 2006 and 2007. Slope and elevation, which are generally negatively correlated with risk of deforestation also decrease substantially with the change in rules: between 2006 and 2007, the mean slope of PSAH areas decreases from 12.241 to 10.964, and the mean elevation decreases from 1737.731 to 1418.720. In addition, the differences in deforestation risk between accepted and rejected properties go from negative (indicating the selection of lower risk properties) in the 2004-2006 period to positive (selection of higher risk properties) in the post-2006 period.

Finally, during the same period, measures of targeting to areas of particular environmental and hydrological concern show little change. Surface

water availability and the likelihood of being located in an overexploited aquifer or protected natural area remain relatively consistent from 2004 to 2010. This indicates that CONAFOR has been able to maintain these environmental goals while increasing the average risk of deforestation and marginality index.

**Table 4: Summary statistics by year for enrolled and rejected PSAH areas, with differences (enrolled-rejected).**

| Variable | | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|
| Slope | Enrolled | 12.350 | 11.859 | 12.241 | 10.964 | 10.697 | 12.745 | 10.755 |
| | Rejected | 11.623 | 11.984 | 9.345 | 10.177 | 11.219 | 11.950 | 12.395 |
| | Difference | 0.727 | -0.125 | 2.896 | 0.787 | -0.522 | 0.795 | -1.640 |
| Elevation | Enrolled | 2093.436 | 1895.637 | 1737.731 | 1418.720 | 1435.744 | 1625.065 | 1381.344 |
| | Rejected | 2035.405 | 1820.489 | 1729.242 | 1611.099 | 1393.201 | 1549.732 | 1565.308 |
| | Difference | 58.031 | 75.148 | 8.489 | -192.379 | 42.543 | 75.333 | -183.964 |
| Surface Water Availability | Enrolled | 6.610 | 6.637 | 6.548 | 6.607 | 7.012 | 6.855 | 6.942 |
| | Rejected | 6.491 | 6.650 | 6.270 | 6.835 | 6.934 | 6.708 | 6.849 |
| | Difference | 0.119 | -0.013 | 0.278 | -0.228 | 0.078 | 0.147 | 0.093 |
| Overexploited Aquifer | Enrolled | 0.128 | 0.276 | 0.271 | 0.177 | 0.140 | 0.212 | 0.116 |
| | Rejected | 0.239 | 0.186 | 0.232 | 0.146 | 0.118 | 0.150 | 0.116 |
| | Difference | -0.111 | 0.090 | 0.039 | 0.031 | 0.022 | 0.062 | 0.000 |
| Distance to a Locality w/ Pop. Over 5000 | Enrolled | 23.947 | 26.734 | 30.760 | 28.471 | 25.203 | 29.391 | 31.156 |
| | Rejected | 24.811 | 22.996 | 25.912 | 30.039 | 27.221 | 28.369 | 32.268 |
| | Difference | -0.864 | 3.738 | 4.848 | -1.568 | -2.018 | 1.022 | -1.112 |
| Risk of Deforestation | Enrolled | 2.241 | 2.321 | 2.246 | 2.994 | 2.914 | 2.469 | 2.747 |
| | Rejected | 2.453 | 2.505 | 2.605 | 2.672 | 2.763 | 2.587 | 2.505 |
| | Difference | -0.212 | -0.184 | -0.359 | 0.322 | 0.151 | -0.118 | 0.242 |
| Priority Mountain | Enrolled | 0.634 | 0.385 | 0.442 | 0.284 | 0.340 | 0.429 | 0.267 |
| | Rejected | 0.531 | 0.487 | 0.371 | 0.249 | 0.179 | 0.170 | 0.145 |
| | Difference | 0.103 | -0.102 | 0.071 | 0.035 | 0.161 | 0.259 | 0.122 |
| Protected Natural Area | Enrolled | 0.287 | 0.257 | 0.211 | 0.182 | 0.168 | 0.220 | 0.297 |
| | Rejected | 0.220 | 0.327 | 0.245 | 0.134 | 0.094 | 0.061 | 0.116 |
| | Difference | 0.067 | -0.070 | -0.034 | 0.048 | 0.074 | 0.159 | 0.181 |
| Municipal Marginality Index 2000 | Enrolled | -0.121 | -0.329 | -0.301 | 0.322 | 0.268 | 0.236 | 0.140 |
| | Rejected | -0.201 | -0.102 | -0.213 | 0.018 | 0.054 | -0.062 | 0.096 |
| | Difference | 0.080 | -0.227 | -0.088 | 0.304 | 0.214 | 0.298 | 0.044 |
| Majority Indigenous | Enrolled | 0.185 | 0.125 | 0.139 | 0.427 | 0.338 | 0.332 | 0.342 |
| | Rejected | 0.115 | 0.168 | 0.158 | 0.244 | 0.246 | 0.302 | 0.228 |
| | Difference | 0.070 | -0.043 | -0.019 | 0.183 | 0.092 | 0.030 | 0.114 |
| Communally Held Property | Enrolled | 0.670 | 0.630 | 0.562 | 0.562 | 0.447 | 0.654 | - |
| | Rejected | 0.569 | 0.668 | 0.479 | 0.460 | 0.430 | 0.603 | - |
| | Difference | 0.101 | -0.038 | 0.083 | 0.102 | 0.017 | 0.051 | - |

## Changes in program rules and eligible zones

Changes in enrollment on the basis of social criteria and risk of deforestation are explained to some extent by changes in program rules and eligible zones. In 2006, the criteria identified by CONAFOR for prioritizing applicants to the PSAH program expanded notably for the first time since the program's inception.

Among the criteria added were environmental considerations, including high surface water scarcity and location within a protected natural area, and social and economic criteria, including location in majority indigenous and marginalized areas. 2006 also saw the introduction of the INE risk of deforestation classification as an enrollment priority.[4]

To understand how the eligible zones impacted the pool of program applicants, we also construct relevant statistics for a sample of randomly selected points within eligible areas defined from 2004-2009 (Table 5). We see that mean values for the risk of deforestation generally increased over time from 2.025 in 2004-2005 to 2.541 in 2009, indicating CONAFOR's efforts to establish eligible zones that captured higher risk forest. As noted above, this did pay off in terms of leading to higher risk lands in later cohorts of the program. With respect to the marginality index, we also see that mean values within each year's eligible zones generally increased over time, with the largest jump from -0.057 in 2006 to 0.351 in 2007 and then a slight decrease in 2008 and 2009. The likelihood of an eligible point being within a majority indigenous municipality rose from 0.249 to .365 between 2004 and 2009. In general, the expansion of the eligible zones in 2007 appears to have allowed for better targeting to areas with high marginality and risk of deforestation on the basis of the new criteria introduced in 2006.

Overall, these results suggest that CONAFOR has generally been able to increase enrollment of the poor and of higher risk forest over time by changing the eligible zones and program rules. They have also successfully selected higher risk and more poor recipients from among the applicant pool. There may still be room to improve targeting on both dimensions, but the decline in the marginality index among later years (from .322 in 2007 to .140 in 2010) suggests they may have already exhausted the straightforward opportunities to attract properties which are both high risk and poor.[5]

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[4] Note that above we see the most notable changes in targeting results occurred between 2006 and 2007, a year after these new criteria were introduced. It is possible that a lag in the recruitment of applicants to the program based on new priorities resulted in a delay in changes in targeting results. In addition, despite the introduction of new priority criteria in 2006, the relatively small size of the eligible zones may have limited the recruitment of well-suited properties until the next year. Between 2006 and 2007, the eligible zones for PSAH enrollment increased in size from 62,807 square kilometers to 210,542 square kilometers, and the number of applicants to the rose from 631 to 1764 Table 2.

[5] An alternate potential mechanism for this change is a shift in the minimum land area for enrollment. Between 2008 and 2009, the minimum land area required for an individual to enroll in the program increased from 20 hectares to 100 hectares. Poorer landowners with smaller plots of land may have been unable to enroll in the program after this change in rules.

**Table 5: Summary statistics by year, all forested points within the eligible zones, 2004-2009**

| Variable | 2004-2005 | 2006 | 2007 | 2008 | 2009 |
|---|---|---|---|---|---|
| Slope (grade) | 12.143 | 12.136 | 12.050 | 12.004 | 12.289 |
| Elevation (m) | 1705.311 | 1548.019 | 1512.555 | 1490.135 | 1522.256 |
| Surface Water Availability | 6.754 | 6.627 | 6.801 | 6.825 | 6.810 |
| Overexploited Aquifer | 0.164 | 0.207 | 0.156 | 0.142 | 0.143 |
| Km to a Locality w/ Pop. > 5000 | 30.370 | 32.691 | 35.230 | 34.493 | 34.525 |
| Risk of Deforestation | 2.025 | 2.286 | 2.574 | 2.555 | 2.541 |
| Priority Mountain | 0.499 | 0.284 | 0.193 | 0.182 | 0.185 |
| Protected Natural Area | 0.292 | 0.165 | 0.095 | 0.091 | 0.086 |
| Municipal Poverty Index 2000 | -0.046 | -0.057 | 0.351 | 0.292 | 0.308 |
| Majority Indigenous | 0.249 | 0.261 | 0.393 | 0.364 | 0.365 |
| Communally Held Property | 0.752 | 0.756 | 0.800 | 0.787 | 0.791 |

## SUMMARY

The PSAH program has the dual goal of decreasing deforestation in areas of water scarcity and alleviating rural poverty. The results of our analysis of enrollment in the program suggest that it has been effective at enrolling lands that have high ecological priority and that are representative of the overall marginality distribution of forested lands. We also find that targeting has improved substantially over time due to changes in the program rules and the eligible zones. In analyzing the characteristics of enrolled versus rejected properties for each year 2004-2010, we found that enrolled properties had higher risk of deforestation and higher degrees of marginality and indigenous populations and that degree of difference increased over time. We attribute this improvement in targeting to refinements in the selection criteria for participants and in the eligible zones.

One potential area for improvement is in terms of selecting properties with even higher risk of deforestation. Even with substantial changes in the eligible zones, the average risk of deforestation among enrolled properties remains somewhat below the national average across all forested lands. Two possible ways to do this are to target further on the basis of multiple characteristics which determine avoided deforestation or to raise the payment amounts. These are discussed further in parts III and IV.

# PART II. ASSESSING SOCIOECONOMIC IMPACTS

In part I, we found that the program was reaching recipients with a high degree of marginalization. We would also like to know whether and how the program may benefit these households and communities. Therefore in this section we ask:

- How are payments distributed within communities?
- What impacts did the program have on wealth, as measured by household assets?
- What impacts did the program have on labor allocation, access to credit, and household production of agriculture and livestock?
- What impacts did the program have on forest management activities?
- What are the perceived benefits of the program?

Our findings are based on responses to the national survey conducted in the summer of 2011 which is described below.

## Section 1: Methods to assess socioeconomic impacts

In order to assess the socioeconomic impacts of the PSAH program, we conducted a national-level field survey of a sample of beneficiary and matched non-beneficiary applicants from the 2008 program cohort. Surveys in communal properties were implemented with both heads of households and community leaders and with private property household heads. Case studies were also conducted in 18 of the survey sites with in-depth interviews conducted with CONAFOR employees, intermediary agents and participants.

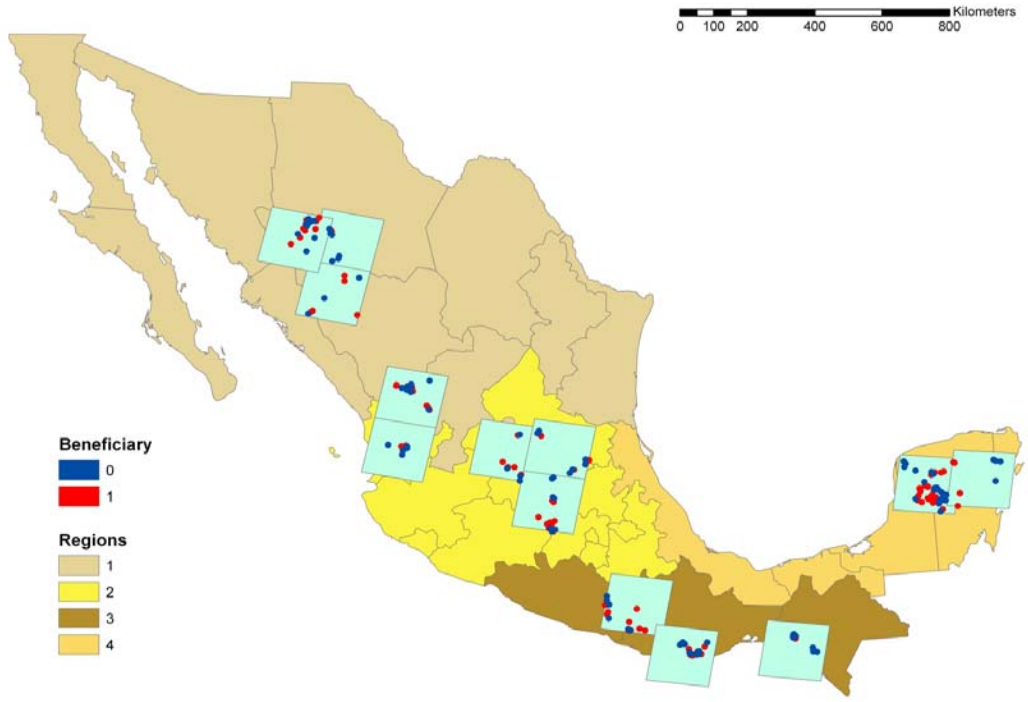
**Survey sample and timing**

We fielded the survey between June and August of 2011. A stratified random sampling strategy was applied by region. The four regions (north, central, southwest and southeast) were determined by dominant ecosystem type and socioeconomic groupings and are shown in Figure 4. Across all regions, a total of 13 Landsat footprints (areas 180x180 sq km) were randomly selected from within the set that contained past images of sufficient quality to monitor deforestation over time.[6] We then identified all 2008 cohort applicants within each footprint and matched them to controls from the applicant pool that did not subsequently become beneficiaries in 2009,2010 or 2011 using nearest-neighbor covariate matching. Matching was conducted applying the Mahalanobis metric within region and tenure type (common property vs. private property) and on the basis of

[6] Analysis of the more detailed Landsat data (30m x 30 m pixels) is currently in process.

the following covariates: distance to the nearest locality with population greater than 5000, elevation, slope, the area of the property submitted to be enrolled, the density of roads within a 50 km buffer, the average locality poverty level in 2005, and the percentage of submitted forest in coniferous forest, oak forest, cloud forest, upland tropical forest and lowland tropical forest. Matches with high distance measures between covariates were eliminated from the possible sample (i.e. because there was no good match available). Within region and tenure type, priority then was given to possible survey properties which had multiple good matches among the controls and vice versa. Some last minute adjustments in the sample were made due to security concerns--this resulted in the swapping of two Landsat footprints for nearby ones and the addition of two footprints in order to increase sampling possibilities among the non-beneficiaries.

**Figure 4: Survey sample and survey regions**




Centroid points of properties surveyed (summer 2011). Total number of properties surveyed = 233.

Surveyors further stratified the sample within common property communities by land-use rights. Based on lists provided by program officers or community leaders, surveyors randomly selected 5 households with full land-use rights and voting power ("ejidatarios") and 5 without ("non-ejidatarios"). The final sample is composed of 118 private households (61 beneficiaries and 57 non beneficiaries) and 1125 households (596 beneficiaries) and (529 non-beneficiaries) distributed over 116 common property communities. Table 6 indicates the breakdown of surveyed households in each region and Figure 3 shows the locations of the beneficiary and non-beneficiary properties (here shown as points rather than polygons).

**Table 6: Sample size of survey and distribution by region**

| Regions | Households in common property | | | Private landowners | | |
|---|---|---|---|---|---|---|
| | Non-beneficiaries | Beneficiaries | Total | Non-beneficiaries | Beneficiaries | Total |
| 1. North | 140 | 138 | 278 | 14 | 15 | 29 |
| 2. Center | 137 | 161 | 298 | 15 | 15 | 30 |
| 3. Southwest | 133 | 150 | 283 | 15 | 16 | 31 |
| 4. Southeast | 119 | 147 | 266 | 13 | 15 | 28 |
| **Total** | **529** | **596** | **1,125** | **57** | **61** | **118** |

Regions as shown in Figure 4.

The reasons for rejection in our surveyed sample are similar to the overall rejected pool. 35% were approved but rejected due to lack of funding, 50% were rejected due to having less than the required percentage of forest cover on the submitted property, 6% were outside of the eligible zones and the remaining 9% had incomplete documentation or did not meet other technical criteria. As shown in Table 7 the survey sample is fairly representative of the regional and ecological distribution of 2008 enrollees in the PSAH.

**Table 7: Distribution of surveyed and enrolled properties by region and ecosystem type, 2008**

| | Oak | Pine | Mixed mesophytic | Tall/medium rainforest | Dry tropical forest | | |
|---|---|---|---|---|---|---|---|
| **Region** | **Surveyed properties** | | | | | **% by region** | **Ha by region** |
| 1 | 62.35 | 52.00 | 0.00 | 0.00 | 11.09 | 38.71 | 483.75 |
| 2 | 24.02 | 15.69 | 0.00 | 0.00 | 3.74 | 12.75 | 159.30 |
| 3 | 13.63 | 32.31 | 100.00 | 27.61 | 8.31 | 22.41 | 280.07 |
| 4 | 0.00 | 0.00 | 0.00 | 72.39 | 76.87 | 26.14 | 326.69 |
| Ha by forest type | 230.09 | 581.64 | 7.90 | 88.82 | 1249.82 | | 143.47 |
| **Region** | **Enrolled properties, 2008** | | | | | | |
| 1 | 52.87 | 44.46 | 1.49 | 0.01 | 17.38 | 31.15 | 572.14 |
| 2 | 27.92 | 22.62 | 9.21 | 2.27 | 12.72 | 17.81 | 327.12 |
| 3 | 18.85 | 31.41 | 85.03 | 27.00 | 17.10 | 28.07 | 515.6 |
| 4 | 0.37 | 1.51 | 4.26 | 70.72 | 52.79 | 22.97 | 421.87 |
| Ha by forest type | 473.88 | 575.28 | 119.59 | 299.6 | 368.38 | | 1836.73 |

Six survey instruments were created: for non-beneficiaries, one survey was generated for private property households, for common property leaders, and for common property households. The same three types were written for beneficiary communities, although these contained an additional set of questions regarding the program. In general, the household surveys included the following broad topics: Housing and locality characteristics, household characteristics (including demographics and employment), land access and holdings, production and income, shocks and credit, household expenses and investments, participation in PSAH and forest management, prices of recent purchases, and, for common properties, community participation. At the community level, survey sections included: community infrastructure and location, participation in community activities, production, government transfers and shocks, perceptions of PSAH benefits, and transactions costs for enrolling in PSAH. Complete copies of the questionnaires have been shared with CONAFOR and are available upon request.

**Evaluation methodology**

The broad strategy used to establish impacts is to make comparisons between the beneficiary and non-beneficiary properties. All of these properties are similar in an important unobservable characteristic: the willingness to participate in a forest conservation program. We know this to be the case since all surveyed properties submitted complete applications to CONAFOR in 2008. The pre-sampling matching beneficiary and non-beneficiary communities helps to minimize observable differences between the two types of properties. Table 8 provides quantitative verification of this assertion. Across many important covariates, common property and private households surveys are very similar – in no case are the differences in wealth, household size, and locational fundamentals more than ¼ of a standard deviation apart, meeting a standard rule of thumb in evaluation methodology (see "normalized difference" column[7]). Furthermore, in many cases recall questions allow us to assess not only changes across beneficiary and non-beneficiary communities at one point in time, but also the "before" and "after" values of key outcomes.

[7] The normalized difference is the differences in average values by treatment status scaled by the square root of the sum of the variance. As opposed, to the traditional t-statistic, this is a scale-free measure of the differences in distribution. Imbens and Wooldrigde (2009) suggest a rule of thumb of one quarter.

## Table 8: Summary statistics: beneficiary and non-beneficiary households

### a. Households living in common property communities

| Variables | Beneficiaries | | Non-beneficiaries | | Norm |
|---|---|---|---|---|---|
| | mean | sd | Mean | sd | diff |
| Inverse proportion wealth index 2007 | 1.913 | 1.079 | 1.906 | 1.032 | 0.005 |
| Inverse proportion wealth index 2011 | 2.355 | 1.023 | 2.299 | 0.975 | 0.040 |
| Price wealth index 2007 | 11.786 | 5.989 | 11.750 | 5.518 | 0.004 |
| Price wealth index 2011 | 12.815 | 6.069 | 12.583 | 5.705 | 0.028 |
| PCA wealth index 2011 | -0.080 | 1.883 | 0.092 | 1.868 | -0.065 |
| PCA wealth index 2007 | 0.828 | 1.950 | 0.924 | 1.885 | -0.035 |
| Log (Elevation) | 6.795 | 1.396 | 6.581 | 1.706 | 0.097 |
| Log (Distance locality>=5000 people) | 3.366 | 0.548 | 3.276 | 0.547 | 0.116 |
| Minutes to nearest town (reported by households) | 71.59 | 70.03 | 68.90 | 65.30 | 0.028 |
| Locality poverty 2005 | 0.675 | 0.855 | 0.512 | 0.952 | 0.127 |
| Municipal poverty 2005 | 0.724 | 0.881 | 0.752 | 1.091 | -0.020 |
| Log (Area) | 6.436 | 1.135 | 6.710 | 0.991 | -0.182 |
| Household size | 4.876 | 2.337 | 4.578 | 2.289 | 0.091 |

### b. Private landowners

| Variables | Beneficiaries | | Non-beneficiaries | | Norm |
|---|---|---|---|---|---|
| | mean | sd | Mean | sd | diff |
| Inverse proportion wealth index 2007 | 2.348 | 0.476 | 2.223 | 0.562 | 0.170 |
| Inverse proportion wealth index 2011 | 2.482 | 0.372 | 2.391 | 0.468 | 0.152 |
| Price wealth index 2007 | 21.477 | 12.852 | 19.186 | 6.515 | 0.159 |
| Price wealth index 2011 | 22.219 | 12.633 | 19.881 | 6.618 | 0.164 |
| PCA wealth index 2011 | 0.251 | 1.841 | -0.284 | 2.007 | 0.196 |
| PCA wealth index 2007 | 0.653 | 1.645 | 0.275 | 1.771 | 0.156 |
| Log (Elevation) | 6.472 | 1.553 | 6.602 | 1.445 | -0.061 |
| Log (Distance locality>=5000 people) | 3.137 | 0.634 | 3.255 | 0.616 | -0.133 |
| Minutes to nearest town (reported by households) | 61.39 | 61.30 | 58.67 | 65.06 | 0.030 |
| Locality poverty 2005 | 0.463 | 0.876 | 0.640 | 1.109 | -0.125 |
| Municipal poverty 2005 | 0.908 | 1.008 | 0.660 | 1.083 | 0.168 |
| Log (Area) | 4.373 | 0.838 | 4.368 | 1.014 | 0.004 |
| Household size | 4.328 | 1.947 | 3.860 | 2.150 | 0.161 |

The price index is measured in 10,000's of pesos. For households living in ejidos, the PCA index ranges from -3.07 to 6.40 and the inverse proportion index ranges from 0 to 4.28. For private households, the PCA index ranges from -5.90 to 3.48 and the inverse proportion index ranges from 0.66 to 2.96.

**Case study methodology**

We also carried out case studies in a subsample of 18 of the survey sites, conducting semi-structured interviews with 48 state-level CONAFOR employees, intermediary agents (e.g. NGOs, private contractors, forestry consultants) and participants who had been most involved in PSAH implementation in each site (see Table 9).

The purpose of these case studies was to understand in a more nuanced way the perceptions and motives of people who had been intimately involved in the implementation of the program at multiple levels with the objective of enriching our understanding of trends we might observe in the quantitative survey or remote sensing data.

**Table 9: Distribution of case study sample by region, tenure type, and role**

| State | Region | Tenure Type | | Interviewee Type | | |
|---|---|---|---|---|---|---|
| | | ***Private Properties*** | ***Communal Properties*** | ***CONAFOR Employees*** | ***Intermediaries*** | ***Participants*** |
| **Chihuahua** | 1 (North) | 0 | 2 | 1 | 2 | 2 |
| **Durango** | 1 (North) | 2 | 0 | 1 | 1 | 2 |
| **Michoacán** | 2 (Central) | 0 | 3 | 3 | 3 | 4 |
| **Oaxaca** | 3 (SW) | 3 | 3 | 4 | 4 | 9 |
| **Yucatán** | 4 (SE) | 3 | 2 | 4 | 4 | 4 |
| **TOTAL** | | **8** | **10** | **13** | **14** | **21** |

Selection of case study sites was not randomized both because of the small sample size and because we had no intentions of conducting statistical analyses on the primarily qualitative data collected. However, in order to obtain relatively equal representation by region, property type and role in the implementation of the project, we did stratify according to these characteristics. Because the overarching question we were asking was, "When do these programs achieve their objectives and under what conditions?" we also stratified the sites according to the CONAFOR state level employees' and our own surveyors' perceptions of functional vs. non-functional project sites, selecting paired sites that were close geographically, but in which the PES program was perceived to have had less socioeconomic and/or environmental impacts.

Interviews were semi-structured. Interview guides were developed with input from CONAFOR personnel at the national level to ensure that the data gathered would be relevant to policy design. The case studies were conducted after the survey had been completed in each site and ranged from August to December 2011. Contact was made with potential interviewees through the same state-level CONAFOR employees who had assisted with survey logistics. Interviews were conducted by five members of our research team: one of the PIs, our research coordinator from Mexico, a PhD student from the University of

Wisconsin, Madison, and two master's students from Duke University, all of whom were fluent in Spanish and had significant experience working in rural Latin America.

For each site, every attempt was made to interview the project participant as well as the CONAFOR employee and intermediary (e.g. NGO employee, private consultant, forester, etc.) who had been most involved with implementing and monitoring the project in the site. Interviews ranged from ½ to 3.5 hours and for participants were normally conducted at the project site. For intermediaries and CONAFOR employees, interviews were conducted in their place of business.

The principal themes touched upon in during the semi-structured interview included:

1. ***Interaction with the program*** (i.e. the process of entering and implementing the program, understanding of program objectives, costs and benefits of participation, and perceptions of program impacts and effectiveness)
2. ***Impact on the local economy*** (i.e. impact on access to or restrictions on credit, generation of employment)
3. ***Interaction with local institutions*** (i.e. direct impact of the program on strength and functionality of local institutions, direct impact of program on rules and sanctions associated with forest access and use)
4. ***Impact on land use decisions*** (i.e. perceptions of changes in land use since program inception, perceptions of the principal threats to forest health, direct impacts of program on forest health, and direct impacts of program on valuation of forest benefits)

Interviews were recorded and transcribed into the original Spanish. Interview transcripts were then imported into the qualitative data analysis software NVivo 9. Full analysis of the case studies is still ongoing but preliminary insights have been included in the sections below as appropriate.

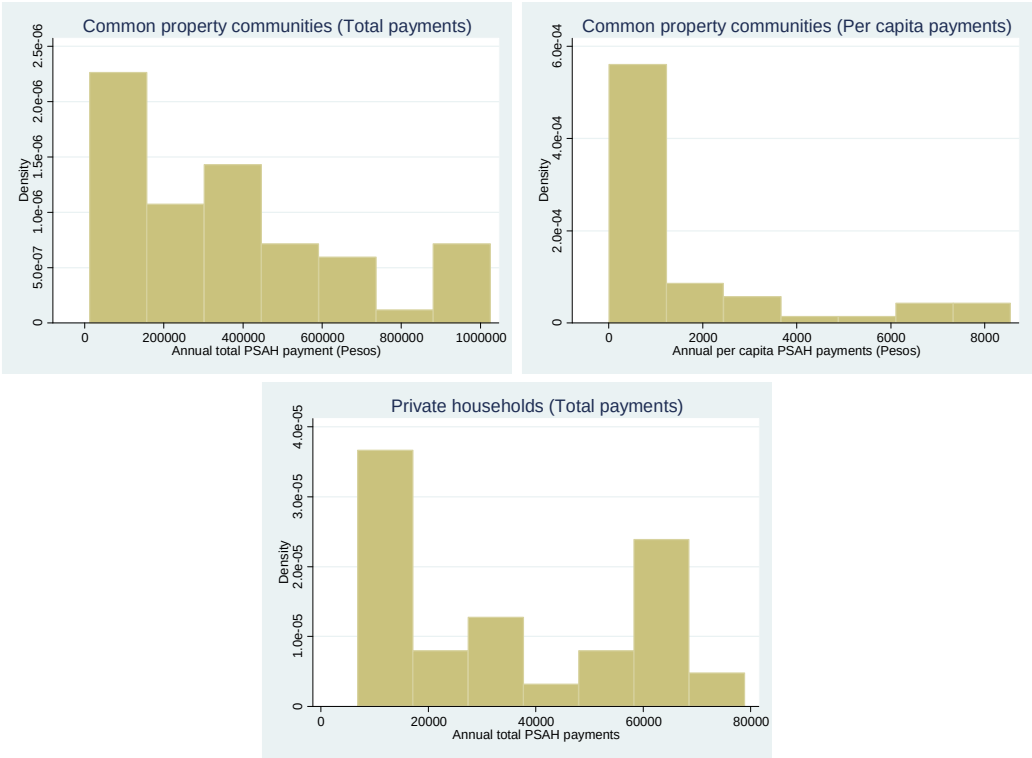
## Section 2: Distribution of payments

This section details the average payment size and distribution of payments within recipient properties of our 2008 survey sample. The annual per capita payment within common property communities is 1,539 Mexican pesos (approximately 130 U.S. dollars). This is higher than the monthly minimum wage in Mexico, which is currently 1,161 pesos. For private households, the average annual payment they received from the program is 35,777 pesos, which we estimate to be approximately 12% of household income.[8] Figure 5 shows the distribution of PSAH payments across beneficiaries. For common properties, these payments are somewhat skewed – larger numbers of ejidos, both on a per capita and total basis, receive a relatively small amount of payments, whereas a few ejidos receive large payments. For private properties, these payments are relatively more evenly distributed.

[8] The mean per capita payment in common property communities was calculated taking into account the annual payment each community receives from the PSAH program and excluding the payments they give for technical support. These numbers are a lower bound as they include the total population in the community, including children, adult women and men, and old persons, as reported by community leaders. The final amount was converted to US dollars using the exchange rate reported for the 15th of July of 2011 (11.72 pesos/ USD). The monthly minimum wage was calculated taking into account the daily minimum wage reported by CONASAMI. The average daily minimum wage in 2011 for the whole country was 58.1 pesos. Assuming there are 20 working days within a month, the monthly minimum wage is 1,161 pesos. The minimum annual total PSAH payment is 12,521 and the maximum is 1,025,505 pesos. The minimum annual per capita PSA payment is 3.61 and the maximum is 8545.87.

For private households, the mean payment per year is 35,777 pesos or approximately 3,053 US Dollars. The minimum annual PSAH payment is 6,836.70 and the maximum is 78,885. The survey we collected does not have information about households' income, so we used income results coming for the National Income and Expenditures survey (ENIGH 2010), collected by INEGI, and assumed that private households in our sample are located in the upper 3 deciles of the income distribution. According to this survey, the average quarterly income for the upper 3 deciles is 72,398 pesos, so average annual income ~ 289,593 pesos. Therefore the PSAH payments represent 12% of this total annual income.

**Figure 5: Distribution of PSAH payments across beneficiaries**




As Section 5 will explain in more detail, a large part of program funds, both for common property communities and private households, seem to be allocated to pay for labor devoted to forest management activities. Within communities participating in the program, there are some differences in how program funds are allocated at the community level. Some communities equally divide the payment among members (a "lump-sum transfer"), others provide wages for performing some specific forest management activities, and others invest in public goods ("non lump-sum transfers"). In some cases, we see a combination of these three strategies[9]. For those communities where payments are given directly to households as lump sum transfers, 92% of them go only to those with land-use rights and the average amount they report they received in the past

[9] The data confirms that when communities distribute funds directly to households, not all of them distribute the total amount. The average proportion distributed is 0.75.

12 months is 12,881 pesos[10]. Table 10 reports the percentage of communities that provide lump-sum transfers by region and shows that most of the communities in the south east region follow this strategy.

**Table 10: Distribution of program funds by region**

| Region | No lump-sum transfers | Lump-sum transfers |
|---|---|---|
| Region 1 (North) | 92.308 | 7.692 |
| Region 2 (center) | 86.667 | 13.333 |
| Region 3 (South West) | 66.667 | 33.333 |
| Region 4 (South East) | 20.000 | 80.000 |
| **Total** | **65.517** | **34.483** |

Note: Numbers reported in each row are the percentage of communities within each region that provide lump-sum transfers and not.

When we compare the characteristics of communities providing lump-sum transfers with those that do not (Table 11), we can see that those providing transfers have, on average, smaller populations and less total land. Also, they have a higher percentage of indigenous population (61% vs. 42%) and a lower percentage of female ejidatarios (8% vs. 26%). Employment characteristics are similar: approximately 72% of the ejidatarios work in agricultural activities and only 6% work off-farm in both communities. There are some differences in the area of forest enrolled in the program. Communities with transfers enrolled, on average, 823 hectares, and those without transfers enrolled 1,141 hectares. In spite of this difference, per capita payments in communities providing lump-sum transfers are more than double those observed in communities without transfers (12,030 vs. 5,352 pesos). Moreover, since the ratio of ejidatarios to non-ejidatarios is lower in communities providing transfers, the per ejidatario program payments are also larger in these communities (46,242 vs. 23,408 pesos).

[10] This number is the average of the payments received by households with land-use rights in our sample. It excludes all households with zero payments. The average over all households with land-use rights is 4,534 pesos.

**Table 11: Community characteristics by transfer type**

| Community characteristics | With lump-sum transfers | No lump-sum transfers | Difference |
|---|---|---|---|
| Total population | 1281.150 | 3089.595 | -1808.445 |
| Total hectares of land in community | 2640.550 | 9121.995 | -6481.445* |
| Area of forest enrolled in program | 823.328 | 1140.989 | -317.661 |
| Locality poverty 2005 | 0.496 | 0.790 | -0.294 |
| Indigenous in sample | 0.610 | 0.418 | 0.192 |
| Ejidatarios no education | 0.166 | 0.235 | -0.069 |
| Ejidatarios that are women | 0.085 | 0.265 | -0.180*** |
| Ejidatarios working off-farm | 0.040 | 0.073 | -0.034 |
| Ejidatarios working agriculture | 0.707 | 0.737 | -0.030 |
| Ratio ejidatarios / non-ejidatarios | 2.822 | 4.098 | -1.276 |
| Total per capita PSAH payments | 12030.198 | 5352.306 | 6677.892* |
| Total per ejidatario PSAH payments | 46242.099 | 23408.070 | 22834.029* |

**SUMMARY**

Information on how payments are distributed from the 2008 survey indicates a wide range of per capita payment amounts and strategies for distributing funds. Three main uses of funds are a) direct lump-sum transfers to community members b) wages for performing forest-management related activities and c) investments in community goods or infrastructure.

## Section 3: Wealth impacts

A goal of Mexico's program and global PES program is to help compensate landowners for the public goods that their land provides. Policymakers have also hoped that payments may also help alleviate poverty. In this section we present the estimates of the average impact on wealth using information on asset holdings as a proxy for material wealth. Clearly there are many dimensions of human well-being that are important and could be affected by the program. We assess impacts on this dimension because it is possible to observe and quantify changes in a way that allows for reasonable comparison across time and across households.

**Assessing wealth impacts**

Survey enumerators collected information on a variety of assets at the household level, ranging in size from a bicycle to an additional room in a house. Presence or absence of these assets was recorded for 2007 (before integration into the program) and in 2011. To identify program impacts, we compare differences over time in ownership of these assets between beneficiaries and non-beneficiaries. It is important to note that there was considerable asset growth over time across the entire sample – for both beneficiaries and non-beneficiaries. For example, the likelihood of beneficiaries owning a car increased by 10 percentage points between 2007 and 2011, but the likelihood of non-beneficiaries having a car also increased by 7 percentage points. Once again, this highlights the danger of misinterpreting changes over time as "impacts", since the actual difference between the time trend of car acquisition between beneficiaries and non-beneficiaries is 3 percent. The estimates that we show use household "fixed effects", which serve to control for characteristics that do not change over time. Since we record a variety of assets, we also report results which aggregate assets using three types of index common in the development literature, which use different weighting schemes.

The first index is created using principal components analysis (PCA) on ordered data (Filmer and Pritchett 2001, Kolenikov and Angeles 2009). This approach gives more weight to observations which provide more information about the variation in the data. The second index, the inverse proportion index, applies weights to the assets which are the inverse of the proportion of households which hold a particular asset in 2007. This gives greater weight to assets which are relatively rare – like cars and computers– and less to more common assets, like televisions. Finally, we construct a price index based on data from consumer agencies in Mexico on the prices of consumer goods and estimates of the values of housing characteristics. In order to measure changes in wealth over time, the 2007 weights or prices are used to construct the indices for 2011 in all cases. Full details of these indices can be found in Appendix A, from Alix-Garcia et al. (2012).

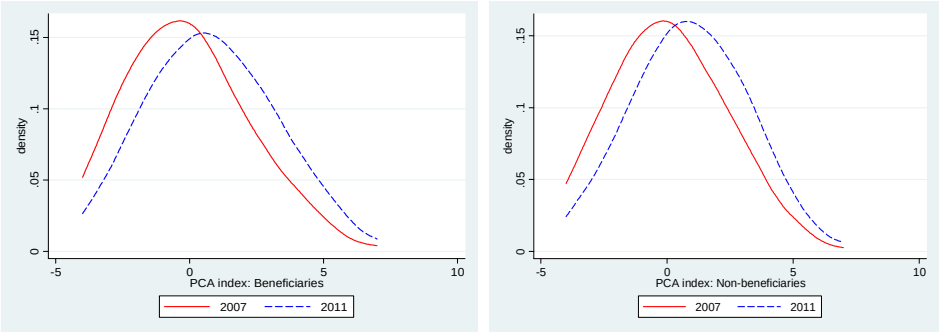
**Wealth impacts: results**

Figure 6 shows kernel density distributions of assets according to the principal components (PCA) index for each of the three groups. The red solid lines show assets in 2007 while blue dotted lines show assets in 2011. Graphs on the left indicate beneficiary households while graphs on the right indicate non-beneficiary households. From this we extract several key insights. First, the overall distributions of beneficiaries and non-beneficiary households are fairly similar at baseline for each of the three sample groups, indicating reasonable balance across the distribution of wealth at baseline. Second, the graphs show that all households have gained assets over this time period, i.e. there is no evidence that participation in the program has made households worse off in an absolute sense. Third, the pattern of gains for beneficiaries and non-beneficiaries are quite similar. Figure 6 indicates that the ejidatario beneficiaries may have increased assets by more than non-beneficiaries, particularly in the middle and at the upper end of the distribution. The non-ejidatario beneficiaries have similar changes to the control group. For the private properties, we notice that the changes over time in assets are smaller but again see similar shifts between beneficiaries and non-beneficiaries over time.

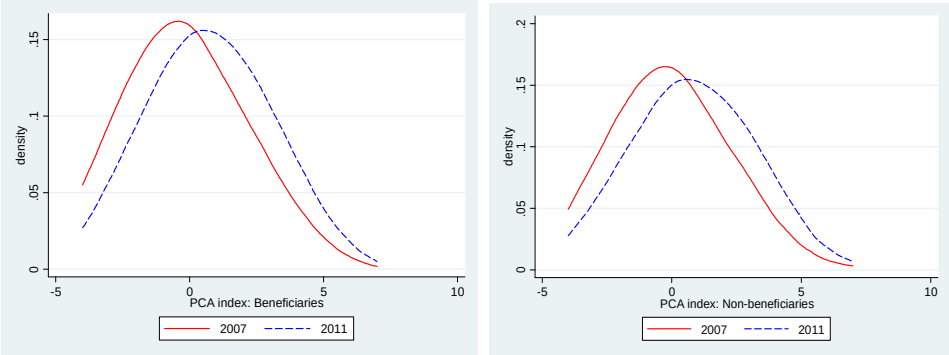
## Figure 6: Distributions of assets over time for Beneficiaries and Non-beneficiaries

Graphs show the density of the PCA index in 2007 (red) and 2011 (dashed blue) for beneficiaries (left) and non-beneficiaries (right). Kernel density graphs with bandwidth = 1.5

### a. Ejidatarios




### b. Non-Ejidatarios




### c. Private properties

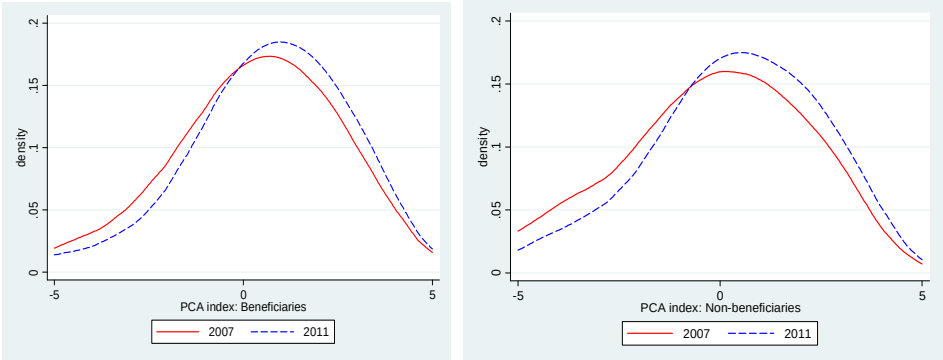


Table 12 shows estimates of program impact on ownership for each asset. The first set of estimates is for households of ejido members with full voting status and land rights (ejidatarios) while the second set is for non-ejidatarios.[11] The third set combines these two groups and weights households by the share of each type of household in the community (weights are the ratio of the proportion of ejidatarios or non-ejidatarios in the population relative to the proportion of ejidatarios or non-ejidatarios in the sample). We interpret these results as the impact of the program on the entire community. The fourth set shows impacts for the private landowner households.

For households in common properties, we find that the program has had possible positive impacts but these are not statistically significant overall. Among ejidatarios, we find marginally significant increases in the probability of owning computers (0.034), cars (0.051) and number of rooms in the house (0.076). Given that the average baseline probabilities of ownership are .03 and .25 for computers and cars, and the average number of rooms is 2, these impacts constitute increases of approximately 100 percent, 20 percent, and 4 percent, respectively. For non-ejidatarios, there are no significant differences in changes in asset ownership. These results are consistent with the distribution of more substantial payments to the ejidatarios versus the non-ejidatarios. We conclude that the program may allow ejidatarios make more significant investments in capital goods and home improvements.

We do not find significant positive or negative impacts for the private households, although the coefficients imply an increase of 0.063 in cars (~9% change) as well as upgrades to walls and flooring materials. We find marginally significant results that the beneficiaries were less likely to acquire a cell phone than non-beneficiaries. It is possible that this may be explained by the greater presence of cell phones in the beneficiary group at baseline (49 percent of beneficiaries had cell phones in 2007, compared to 42 percent of non-beneficiaries) or by differential changes in access to coverage across this period.

[11] Note that members of comunidades, in which all members have full rights, are grouped with ejidatarios.

Table 12. Impacts of PSAH on individual assets: household fixed effects, linear model, binary treatment

| | TV | Refrigerator | Computer | Car | Stove | Phone | Cell phone | Wall | Floor | # Rooms |
|---|---|---|---|---|---|---|---|---|---|---|
| **Ejidatarios** | | | | | | | | | | |
| Beneficiary | -0.056 | 0.004 | 0.034* | 0.051* | -0.019 | 0.026 | 0.033 | -0.007 | 0.003 | 0.076* |
| | (0.037) | (0.033) | (0.020) | (0.028) | (0.030) | (0.021) | (0.041) | (0.079) | (0.048) | (0.043) |
| N | 1423 | 1425 | 1426 | 1426 | 1425 | 1426 | 1426 | 1418 | 1424 | 1424 |
| Baseline mean | 0.499 | 0.369 | 0.031 | 0.254 | 0.350 | 0.135 | 0.191 | 4.336 | 1.64 | 1.963 |
| **Non-ejidatarios** | | | | | | | | | | |
| Beneficiary | -0.032 | -0.034 | 0.004 | -0.033 | 0.056 | -0.005 | 0.084 | 0.070 | 0.033 | -0.029 |
| | (0.049) | (0.048) | (0.023) | (0.033) | (0.037) | (0.029) | (0.056) | (0.092) | (0.068) | (0.070) |
| N | 762 | 761 | 762 | 762 | 762 | 762 | 761 | 761 | 760 | 759 |
| Baseline mean | 0.501 | 0.346 | 0.045 | 0.215 | 0.394 | 0.097 | 0.228 | 4.291 | 1.642 | 1.81 |
| **Households in common properties (weighted)** | | | | | | | | | | |
| Beneficiary | -0.045 | -0.022 | 0.028 | -0.000 | 0.047 | 0.002 | 0.124*** | 0.104 | 0.042 | 0.016 |
| | (0.054) | (0.043) | (0.017) | (0.025) | (0.030) | (0.028) | (0.047) | (0.091) | (0.065) | (0.057) |
| N | 2035 | 2036 | 2038 | 2038 | 2037 | 2038 | 2037 | 2029 | 2035 | 2034 |
| Baseline mean | 0.461 | 0.349 | 0.053 | 0.227 | 0.363 | 0.122 | 0.21 | 4.235 | 1.648 | 1.862 |
| **Private landowners** | | | | | | | | | | |
| Beneficiary | -0.021 | -0.054 | -0.027 | 0.063 | -0.021 | -0.020 | -0.138* | 0.033 | 0.063 | -0.114 |
| | (0.044) | (0.037) | (0.065) | (0.052) | (0.038) | (0.051) | (0.079) | (0.080) | (0.046) | (0.090) |
| N | 236 | 236 | 236 | 236 | 235 | 236 | 235 | 236 | 236 | 234 |
| Baseline mean | 0.863 | 0.829 | 0.308 | 0.675 | 0.812 | 0.547 | 0.457 | 5.12 | 2.197 | 3.44 |

* p< .10 ** p < .05 *** p < .01

Coefficients and standard errors in parentheses for household fixed effects model as described in Alix-Garcia et al. 2012. Mean at baseline gives the mean proportion of the asset owned among all households in 2007

Table 13 gives results for each of the three household wealth indices which aggregate assets. For common property households, being a beneficiary has, on average, a positive but not statistically significant effect for each of the three indices. The weighted sample results show a 0.158 increase for the PCA index, a 0.058 increase for the inverse proportion index and a 0.092 increase in the price index. To get a sense for magnitudes, the price index is measured in 10,000's of pesos, so a coefficient of 0.092 indicates that the program resulted in an additional 900 pesos more of assets. Compared to the average baseline value among the beneficiaries of 11.3, this represents an approximately 0.8% change. For the private landowners, the estimated effect is larger, at 0.241, but the baseline value is also higher, at 20.4, so in percentage terms, this also implies a change of approximately 1.1% in assets. We note however that among private households, the results are negative for the PCA index and inverse proportion index. This inconsistency in signs leads us to conclude that there is no robust detectable effect on private households' assets.

**Table 13: Impacts of PSAH on asset indices: household fixed effects, linear model, binary treatment**

| **Dependent variable:** | **Index (PCA)** | **Index (Inverse proportion)** | **Index (Prices)** |
|---|---|---|---|
| **Ejidatarios sample** | | | |
| Beneficiary | 0.072 | 0.050 | 0.225 |
| | (0.098) | (0.052) | (0.156) |
| N | 1412 | 1414 | 1412 |
| Baseline mean | -0.009 | 1.885 | 11.96 |
| **Non-ejidatarios sample** | | | |
| Beneficiary | 0.080 | 0.041 | -0.112 |
| | (0.132) | (0.075) | (0.186) |
| N | 753 | 758 | 757 |
| Baseline mean | -0.088 | 1.912 | 11.184 |
| **Weighted sample** | | | |
| Beneficiary | 0.158 | 0.058 | 0.092 |
| | (0.122) | (0.072) | (0.153) |
| N | 2017 | 2022 | 2020 |
| Baseline mean | -0.121 | 1.875 | 11.306 |
| **Private landowners** | | | |
| Beneficiary | -0.168 | -0.041 | 0.241 |
| | (0.145) | (0.045) | (0.265) |
| N | 232 | 234 | 232 |
| Baseline mean | 0.00 | 2.289 | 20.401 |

* p< .10 ** p < .05 *** p < .01
Coefficients and standard errors in parentheses for household fixed effects model as described in equation (2). Mean at baseline gives the mean of the relevant index among all households in 2007.

These results are somewhat surprising, but consistent with the qualitative information at our disposal. The consensus from the case study interviews that we conducted with program beneficiaries, intermediaries and CONFOR state-level program administrators was that socioeconomic benefits at the household level were perceived to fairly small. Many interviewees mentioned notable exceptions, common properties in which payments were high per capita because of the small number of ejidatarios and/or the large number of hectares of forest entered in the program. We have examined the possibility of differential results according to whether or not a household was located in an indigenous community, by baseline municipal poverty, and by the characteristics of the land that they enrolled. By these measures, we do not see differential results. However, we are continuing to explore potential dimensions along which there might be heterogeneity in program impacts.

**SUMMARY**

When considering impacts on overall household wealth, we find that all households on average are gaining wealth over time, but wealth increases for beneficiaries are not significantly larger than those for non-beneficiaries. We interpret these results as a positive indication that PES is not making households worse off, although it also does not appear to be conferring large surplus rents to individual landowners which are showing up in asset growth. This may indicate that the size of the payments is relatively small compared to the sum of opportunity costs, transaction costs and forest maintenance costs of participating, or that payments are being channeled to other uses. It may also be the case that the program impacts wealth and welfare through longer term changes which we cannot measure directly with our survey and case studies, although they may give us some insight into investment and behavioral changes that could have long term impacts. We explore these possibilities in the next sections.

## Section 4: Labor, Credit, and Production

This section assesses the possibility that the program has affected household production through changes in allocation of labor, perceived credit constraints, or agricultural and pastoral production decisions. These possible effects of the program are important in assessing whether the program has had major impacts on livelihood strategies and whether household may be making changes that could result in additional income generation over the longer term. We begin by discussing occupations in general, and then move to agricultural production, investment, and credit.

**Labor impacts: primary occupations**

Table 14 indicates the percentages of people engaged in each type of primary labor activity in 2007 and 2011. The vast majority of males (over 60%) between 22 and 76[12] in the ejidos identify agriculture as their primary activity, both in 2007 and 2011, with no significant differences between beneficiaries and non-beneficiaries over time. For women in this age group, the main activity is housewife/student (nearly 80%), followed by services (approximately 12%,). Beneficiary women are slightly more likely to be working in services in 2007, but there are no significant changes between the beneficiaries and non-beneficiaries over time. In private households the largest employment sector for male beneficiaries is services (around 45% in both years), followed by agriculture. There is some deviation between beneficiaries and non-beneficiaries in this sample, with a larger percentage of non-beneficiaries employed in agriculture in 2007 (37% versus 25% of beneficiaries). The vast majority of women 22-76 in private households (beneficiary and non-beneficiary) identify as students or housewives.

There is little evidence that the program has generated significant change in the occupational choice of beneficiaries. On average, we see little difference in the primary and secondary activities between beneficiaries and non-beneficiaries before and after receiving the program. This is also reflected in our income shares data, which shows no significant changes over time in the shares of household income from different sources. The two exceptions to this are that we observe a small but greater increase in livestock activities of non-beneficiary private households, suggesting the program has either reduced the need to expand

[12] An age range of 18-72 years old was considered for the baseline (2007). This decision was made based on sample statistics about the approximate average age of entry and exit from the labor force. In addition, the lower bound was chosen taking into consideration that this is the majority of age in Mexico and also when most young people finish high school. The upper bound is the value reported by OECD for males as the average age of exit from the labor market (72.2) (OECD 2011), it is also close to the one observed in the sample.

herds or reduced the area in which grazing might take place. Moreover, for private households participating in the program we also observed a small but significant increase in the number of people not working. It is possible that the extra cash they receive from the program allows them to retire earlier or to enter to the job market later. When we divide the sample by age, we see that the increase in the number of people not working comes mostly from young adults between 22 and 30 years old.

**Table 14: Employment shares and changes in employment 2007-2011 (primary activity)**

| Sector of employment | 2007 Benef | 2007 Non-benef | 2007 Diff. | 2011 Benef | 2011 Non-Benef | 2011 Diff. | Diff-in-Diff |
|---|---|---|---|---|---|---|---|
| **Common property communities** | | | | | | | |
| Agriculture | 0.331 | 0.321 | 0.009 | 0.335 | 0.324 | 0.011 | 0.002 |
| Livestock | 0.021 | 0.040 | -0.019** | 0.018 | 0.041 | -0.023*** | -0.004 |
| Forestry | 0.021 | 0.012 | 0.009 | 0.023 | 0.021 | 0.002 | -0.007 |
| Services | 0.190 | 0.167 | 0.023 | 0.197 | 0.178 | 0.018 | -0.005 |
| House/Student | 0.404 | 0.428 | -0.024 | 0.396 | 0.402 | -0.006 | 0.018 |
| Did not work | 0.033 | 0.032 | 0.001 | 0.032 | 0.034 | -0.002 | -0.004 |
| **Private households** | | | | | | | |
| Agriculture | 0.133 | 0.207 | -0.073 | 0.127 | 0.213 | -0.086* | -0.013 |
| Livestock | 0.067 | 0.053 | 0.013 | 0.061 | 0.080 | -0.019 | -0.033* |
| Forestry | 0.000 | 0.000 | 0.000 | 0.012 | 0.000 | 0.012 | 0.012 |
| Services | 0.364 | 0.260 | 0.104* | 0.406 | 0.320 | 0.086 | -0.018 |
| House/Student | 0.412 | 0.440 | -0.028 | 0.333 | 0.353 | -0.020 | 0.008 |
| Did not work | 0.024 | 0.040 | -0.016 | 0.061 | 0.033 | 0.027 | 0.043* |

When we differentiate between households living close to and far from urban centers, we see more significant impacts on labor activities. For private households living closer to urban areas, there is a significant impact of the program on livestock activities: beneficiaries are less likely to be employed in livestock activities over time. More beneficiary private households also appear to stop working, perhaps due to the increased income from the program. For private households living far from urban areas, there is a significant increase in participation in off-farm activities. For common property households living close to urban areas, the program appears to decrease employment in forestry when this was a households' main activity. For those living far from urban areas, the program increases work in the forest as a secondary activity. It is important to mention that forest activities could include either conservation or extraction activities. In this sense, it is possible that those living closer to urban areas and for whom forestry is their main activity are mostly involved in extraction activities. If this is the case, then the program might be having a positive effect in limiting these activities in areas with high risk of deforestation.

**Table 15: Changes in employment participation of beneficiaries with respect to non-beneficiaries from 2007 to 2011 (percentage points)**

**Private households**

| Sectors of employment | Households living far away from urban areas | | Households living close to urban areas | |
|---|---|---|---|---|
| | Primary activity | Secondary activity | Primary activity | Secondary activity |
| Agriculture | 2.0 | 0.0 | -2.7 | -0.9 |
| Livestock | 0.0 | 0.0 | -4.9* | 0.0 |
| Forestry | 0.0 | 0.0 | 1.7 | -0.9 |
| Services / Off-farm | 0.0 | 8.5* | -2.9 | -6.4 |
| House/Student | -4.0 | -2.1 | 3.6 | -0.9 |
| Did not work | 2.0 | -6.4 | 5.2* | 9.2 |

**Common property communities**

| Sectors of employment | Households living far away from urban areas | | Households living close to urban areas | |
|---|---|---|---|---|
| | Primary activity | Secondary activity | Primary activity | Secondary activity |
| Agriculture | -0.2 | 1.9 | 0.6 | -1.8 |
| Livestock | 0.6 | -0.8 | -1.1 | 1.0 |
| Forestry | 0.1 | 2.0* | -1.3* | 0.1 |
| Services / Off-farm | -1.4 | 0.5 | 0.2 | 3.0 |
| House/Student | 0.7 | 0.1 | 2.1 | -0.1 |
| Did not work | 0.2 | -3.7 | -0.5 | -2.2 |

Note: Households living far away from urban areas are those living above the mean distance observed in the sample to localities with more than 5000 people. Those living close to urban areas are below this mean distance. Numbers reported in the tables show the employment participation increases or decreases in percentage points for beneficiaries with respect to non-beneficiaries from 2007 to 2011.

**Labor impacts: sectoral shifts**

Although we do not see large impacts of the program on the main employment activities of the participants as a result of the program, this does not indicate that there has been no change. Indeed, there has been some shifting between sectors, which can be seen by examining transition matrices for beneficiaries and non-beneficiaries. The results for households living in common property communities are shown in Table 16. These matrices show the principal activity in 2007 in the first column, and the principal activity in 2011 across the top row. The diagonal entries should be interpreted as the percentage of individuals who did not change activity over the two time periods. For example, among beneficiary males living in common property communities, 92.74% who worked in agriculture in 2007 remain working primarily in agriculture in 2011. For males, there appear to be more beneficiaries moving from livestock activities into agriculture, while we see

more non-beneficiary males remaining in livestock and only a very small percentage shifting into agriculture. Among females, the majority among both beneficiaries and non-beneficiaries remain employed in agriculture or in services. For females, we see more beneficiaries than non-beneficiaries that were not-working in the baseline move into off-farm services in 2011.

**Table 16: Employment transition matrices, ejido men & women, 22-76 years**

**SAMPLE: MALES BETWEEN 22-76 YEARS OLD: BENEFICIARIES**

| **Main activity Beneficiaries** | | **2011** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Livestock | Forestry | Services | House /Studies | Does not work | Total |
| **2007** | Agriculture | 92.74 | 0.48 | 0.97 | 3.15 | 0 | 2.66 | 100 |
| | Livestock | 23.08 | 65.38 | 0 | 11.54 | 0 | 0 | 100 |
| | Forestry | 13.79 | 0 | 75.86 | 10.34 | 0 | 0 | 100 |
| | Services | 11.24 | 0.59 | 1.78 | 84.02 | 0 | 2.37 | 100 |
| | House/Studies | 31.58 | 2.63 | 2.63 | 13.16 | 47.37 | 2.63 | 100 |
| | Does not work | 0 | 0 | 0 | 21.05 | 0 | 78.95 | 100 |
| | Total | 61.1 | 3.03 | 4.32 | 24.5 | 2.59 | 4.47 | 100 |

**NON-BENEFICIARIES**

| **Main activity Non-beneficiaries** | | **2011** | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Livestock | Forestry | Services | House /Studies | Does not work | Total |
| **2007** | Agriculture | 93.65 | 0.28 | 1.38 | 3.59 | 0 | 1.1 | 100 |
| | Livestock | 2.56 | 84.62 | 2.56 | 5.13 | 0 | 5.13 | 100 |
| | Forestry | 13.33 | 0 | 80 | 6.67 | 0 | 0 | 100 |
| | Services | 11.89 | 1.4 | 2.8 | 82.52 | 0 | 1.4 | 100 |
| | House/Studies | 15.15 | 9.09 | 0 | 30.3 | 36.36 | 9.09 | 100 |
| | Does not work | 10 | 5 | 0 | 10 | 5 | 70 | 100 |
| | Total | 59.8 | 6.54 | 3.59 | 23.86 | 2.12 | 4.08 | 100 |

**SAMPLE: FEMALES BETWEEN 22 -76 YEARS OLD: BENEFICIARIES**

| Main activity Beneficiaries | | 2011 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Livestock | Forestry | Services | House /Studies | Does not work | Total |
| 2007 | Agriculture | 83.33 | 2.78 | 0 | 2.78 | 11.11 | 0 | 100 |
| | Livestock | 0 | 50 | 0 | 0 | 50 | 0 | 100 |
| | Forestry | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Services | 0 | 0 | 1.12 | 83.15 | 15.73 | 0 | 100 |
| | House/Studies | 0.2 | 0.2 | 0 | 3.52 | 95.11 | 0.98 | 100 |
| | Does not work | 0 | 0 | 0 | 15.38 | 57.69 | 26.92 | 100 |
| | Total | 4.67 | 0.45 | 0.15 | 14.61 | 78.31 | 1.81 | 100 |

**NON-BENEFICIARIES**

| Main activity Non-beneficiaries | | 2011 | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Livestock | Forestry | Services | House /Studies | Does not work | Total |
| 2007 | Agriculture | 83.33 | 0 | 8.33 | 4.17 | 4.17 | 0 | 100 |
| | Livestock | 0 | 100 | 0 | 0 | 0 | 0 | 100 |
| | Forestry | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Services | 0 | 0 | 0 | 82.46 | 15.79 | 1.75 | 100 |
| | House/Studies | 0.62 | 0 | 0.21 | 3.95 | 93.14 | 2.08 | 100 |
| | Does not work | 0 | 0 | 0 | 5.56 | 66.67 | 27.78 | 100 |
| | Total | 3.9 | 1.53 | 0.51 | 11.54 | 79.8 | 2.72 | 100 |

## Labor impacts: Youth

So far we have looked at the labor impacts of individuals above 22 years old, but one possible and potentially positive impact of program payments is that they induce older children to stay in school longer. When we compare schooling outcomes between beneficiaries and non-beneficiaries living in common property communities we don't see any significant differences in the proportion of children enrolled in school, both for younger (6-17 years old) or older kids (18-23 years old). However, when we compare households living in communities where program funds are distributed as lump-sum transfers with those living in communities where funds are not distributed, we do observe a positive effect of payments particularly on the children of ejidatarios. In general, transfers seem to help ejidatarios to keep both their younger and older kids in school. For private households, we also see that payments might be helping households to keep their older kids in school. On average, 77% of children of beneficiary households remain in school after 18 years old, while only 45% of non-beneficiary children remain in school at this age.

## Table 17: Proportion of children attending school

**Common property communities**

| | 6-17 years old | | | 18-23 years old | | |
|---|---|---|---|---|---|---|
| | **Beneficiaries** | **Non-beneficiaries** | **Diff.** | **Beneficiaries** | **Non-beneficiaries** | **Diff.** |
| All simple | 0.789 | 0.818 | -0.029 | 0.166 | 0.191 | -0.025 |
| Ejidatarios | 0.778 | 0.814 | -0.037 | 0.163 | 0.193 | -0.030 |
| Non-ejidatarios | 0.805 | 0.828 | -0.024 | 0.172 | 0.187 | -0.015 |

| | 6-17 years old | | | 18-23 years old | | |
|---|---|---|---|---|---|---|
| | **Lump-sum transfers** | **No lump-sum transfers** | **Diff.** | **Lump-sum transfers** | **No lump-sum transfers** | **Diff.** |
| All simple | 0.733 | 0.809 | -0.076* | 0.127 | 0.195 | -0.068 |
| Ejidatarios | 0.754 | 0.784 | -0.030 | 0.165 | 0.171 | -0.007 |
| Non-ejidatarios | 0.672 | 0.841 | -0.169** | 0.064 | 0.238 | -0.174* |

**Private households**

| | **Beneficiaries** | **Non-beneficiaries** | **Diff.** |
|---|---|---|---|
| **6-17 years old** | 0.843 | 0.788 | 0.055 |
| **18-23 years old** | 0.697 | 0.438 | 0.259* |

**Agricultural production**

It is possible that the program provides beneficiaries with the possibility of investing in agriculture in such a way to make it more profitable. Less optimistically, critics of PES have expressed concern that such programs might negatively impact food security. In order to further examine this possibility, we consider responses to the section of the survey devoted to agricultural production.

Table 18 indicates results from questions about household participation in agriculture, area of land farmed, and amount produced of the 5 most significant cash crops. Among both private properties and common properties, there were no large differences over time in participation in agriculture—in fact slightly more beneficiary households reported participating in agriculture in 2011 than in 2007. Both groups decreased the average amount of land used between 2007 and 2011, possibly suggesting intensification of agricultural practices. The number of crops cultivated also increases over time for beneficiaries, mirroring a similar trend among non-beneficiaries. There are also no significant changes, on average, in the number of crops sold in the market. Among private households, we do see a difference in the amount of labor hired to assist in agricultural production for private households – the difference in labor hired between beneficiaries and non-beneficiaries over time was 3.5 individuals. It is important to note, however, that most of this difference is driven by a decrease in hiring among non-beneficiary private households: the increase over time within beneficiary households is .91 people on average. The number of people hired in beneficiary communities is quite similar over time.

**Table 18: Participation in agriculture, average land use, and hiring of labor**

| | Propiedades comunales | | | Propiedades Privadas | | |
|---|---|---|---|---|---|---|
| **Agricultural production** | **Benef** | **Non- benef** | **Diff** | **Benef** | **Non-benef** | **Diff** |
| Participation in agriculture (2011) | 0.837 | 0.800 | 0.038 | 0.590 | 0.526 | 0.064 |
| Participation in agriculture (2007) | 0.822 | 0.775 | 0.047 | 0.541 | 0.561 | -0.020 |
| Change in participation | 0.015 | 0.025 | -0.009 | 0.049 | -0.035 | 0.084 |
| Land used for cultivation (2011) | 4.884 | 3.487 | 1.397 | 13.625 | 22.379 | -8.754 |
| Land used for cultivation (2007) | 5.030 | 3.743 | 1.287 | 12.788 | 19.636 | -6.848 |
| Change in land used | -0.146 | -0.256 | 0.110 | 0.837 | 2.743 | -1.906 |
| Average # of people hired to help (2011) | 1.287 | 0.744 | 0.543 | 3.444 | 9.733 | -6.289 |
| Average # of people hired to help (2007) | 1.194 | 0.744 | 0.450 | 2.531 | 12.323 | -9.791 |
| Change in labor hired | 0.093 | 0.000 | 0.093 | 0.913 | -2.589 | 3.502 |
| Number of crops cultivated (2011) | 2.363 | 2.331 | 0.032 | 2.306 | 2.433 | -0.128 |
| Number of crops cultivated (2007) | 2.244 | 2.234 | 0.010 | 2.273 | 2.281 | -0.009 |
| Change in number of crops cultivated | 0.119 | 0.097 | 0.022 | 0.033 | 0.152 | -0.119 |
| Average # products sold in market (2011) | 0.1937 | 0.188 | 0.006 | 0.3925 | 0.4136 | -0.021 |
| Average # products sold in market (2007) | 0.2275 | 0.196 | 0.031 | 0.3284 | 0.3708 | -0.042 |
| Change in # sold in market | -0.034 | -0.008 | -0.026 | 0.064 | 0.043 | 0.021 |

Table 19 indicates whether there have been changes in the composition of crop grown over time and compares differences between beneficiaries and non-beneficiares. For this analysis, we break crops down into 5 categories. Traditional staple crops include maize and beans. Staple/ cash crops include potatoes, yucca, squash, chilacayote, camote, and ejote. Permanent and seasonal cash crops includes all other vegetables and fruits, sugar cane, and coffee. Grains includes oats, wheat, sorghum, and others.

There are only small changes in the composition of crops grown by households. Here we see among common property beneficiary households a small decrease in the number of households growing traditional staple crops (around 4 percent), a small increase in the production of other grains (2 percentage points from a baseline of 3.5%), and small increases in seasonal and permanent cash crop production (.31 and .16 percentage points, but from baselines of 1 and 3.4 percent). Among private beneficiary households we observe a slight decrease in the production of grains, no changes in the production of staple crops, and somewhat larger increases in the proportion of households growing seasonal and permanent cash crops (between 3 and 4 percentage points, respectively).

**Table 19: Changes in crops grown: percentage of households which grew each crop category in each year and differences**

| | Propiedades Comunales | | | Propiedades privadas | | |
|---|---|---|---|---|---|---|
| **Crop type** | **Benef** | **Non benef** | **Diff** | **Benef** | **Non benef** | **Diff** |
| Grew Traditional Staple Crops 2011 | 71.14 | 69.94 | 1.20 | 27.87 | 33.33 | -5.46 |
| Grew Traditional Staple Crops 2007 | 72.99 | 69.00 | 3.99 | 27.87 | 35.09 | -7.22 |
| **Change** | **-1.85** | **0.94** | **-2.79** | **0.00** | **-1.76** | **1.76** |
| Grew Grains 2011 | 5.54 | 1.51 | 4.03 | 4.92 | 0.00 | 4.92 |
| Grew Grains 2007 | 3.52 | 1.32 | 2.20 | 6.56 | 3.51 | 3.05 |
| **Change** | **2.02** | **0.19** | **1.83** | **-1.64** | **-3.51** | **1.87** |
| Grew Staple/Cash crops 2011 | 0.50 | 1.13 | -0.63 | 0.00 | 0.00 | 0.00 |
| Grew Staple/Cash crops 2007 | 0.17 | 0.19 | -0.02 | 0.00 | 0.00 | 0.00 |
| **Change** | **0.33** | **0.94** | **-0.61** | **0.00** | **0.00** | **0.00** |
| Grew Permanent cash crops 2011 | 3.52 | 4.35 | -0.83 | 21.31 | 14.04 | 7.27 |
| Grew Permanent cash crops 2007 | 3.36 | 4.35 | -0.99 | 18.03 | 14.04 | 3.99 |
| **Change** | **0.16** | **0.00** | **0.16** | **3.28** | **0.00** | **3.28** |
| Grew Seasonal cash crops 2011 | 1.51 | 0.57 | 0.94 | 1.64 | 0.00 | 1.64 |
| Grew Seasonal cash crops 2007 | 1.01 | 0.38 | 0.63 | 0.00 | 1.75 | -1.75 |
| **Change** | **0.50** | **0.19** | **0.31** | **1.64** | **-1.75** | **3.39** |
| Grew Other crops 2011 | 0.34 | 1.32 | -0.98 | 1.64 | 1.74 | -0.10 |
| Grew Other crops 2007 | 0.17 | 1.13 | -0.96 | 1.64 | 0.00 | 1.64 |
| **Change** | **0.17** | **0.19** | **-0.02** | **0.00** | **1.74** | **-1.74** |

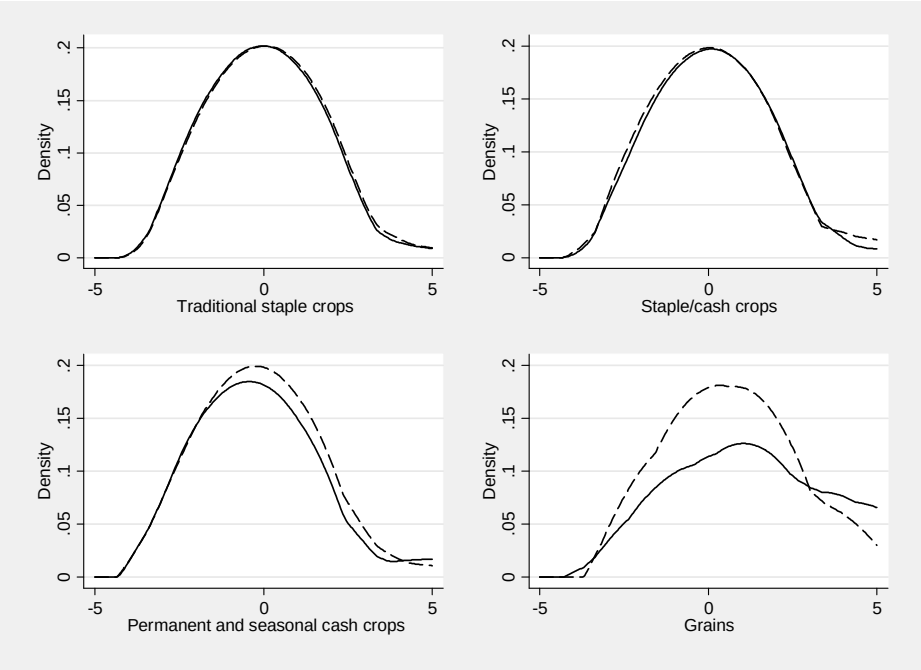
Note: The category Staple/cash crops refers to crops such as Yuca, Jicama, Calabaza, Sweet potatoes and Potatoes which are both food and cash crops.

In order to get a sense for the aggregate value of crops being grown, we construct a measure of the value (or revenues) per hectare: i.e. the sum of price*production quantity for each crop divided by the total land devoted to agriculture. We find that the median value per hectare of the agricultural land in common properties has increased over time, from 1603 pesos per hectare (approximately $137 USD) to 1891 ($162 USD) in ejidos. However, there is no significant difference between the increase in agricultural value per hectare in beneficiary versus non-beneficiary communities. This again suggests that while beneficiary households are not worse off due to the program, we also do not see large increases in production as measured by production revenues.

We observe some heterogeneity in the farming of cash crops, particularly within the common properties. We divide the sample between relatively poor and relatively rich ejidos[13], since poor households are more likely to be credit constrained, in which case the payments might allow for an expansion of production. We observe that beneficiaries in poor ejidos (**Figure 7**) are more likely to increase their production of cash crops, whereas rich beneficiaries (Figure 8) appear to decrease their dependence upon cash crops and increase their production in the category of "staple/cash." The figures show the changes in the distribution of the quantity of the different crop categories for poor and rich within beneficiary (red dotted line) and non-beneficiary (solid blue line) ejidos. Shifts to the right in the lines indicate increases in the average value of crops in different categories. In this preliminary analysis, it looks as if poorer households are responding to the program not by farming more land, but rather by switching to more profitable crops, which should work to minimize displacement of deforestation that might potentially result from the program.

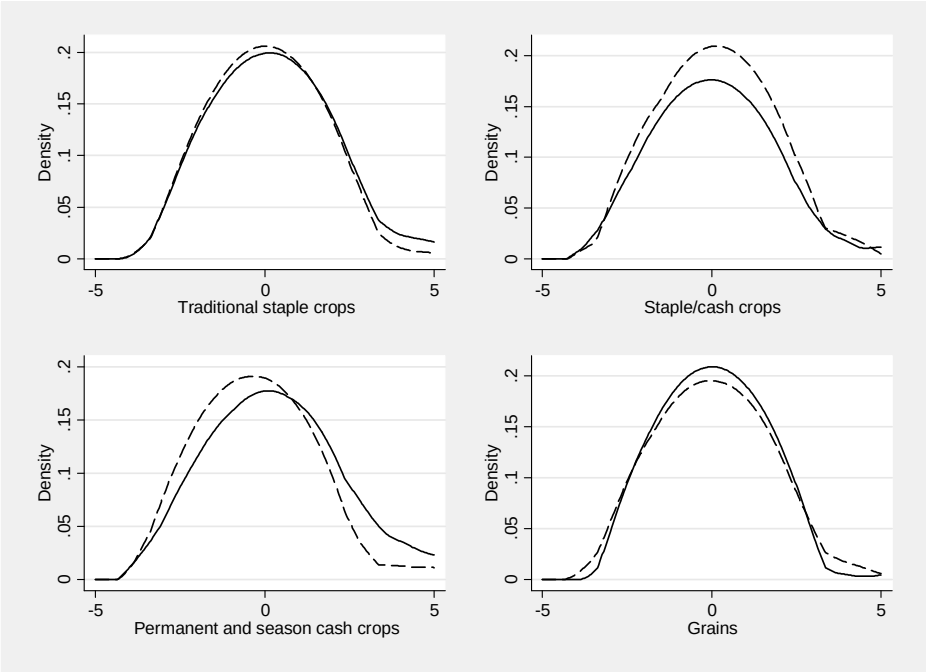
[13] To make this division we first calculated the average value of the PCA wealth index in 2007 at the community level considering households' wealth indices. For more details about this index, look at Section 3: Wealth impacts. Poor ejidos were then defined as those below the median value of this distribution, and rich ejidos are those above this median value.

**Figure 7: Distribution of the change in crop quantities, 2007-2011, for poor common property households**




Kernel density graphs for different crop types. The dotted line indicates beneficiaries and the solid line non-beneficiaries. The crops in the different categories are as follows: traditional staple crops: maiz and frijol; staple/cash crops: papa, chilacayote, camote, jicama, ejote, yucca, calabaza; permanent and seasonal cash crops: all hortalizas and fruits, sugar cane, and coffee; grains: avena, cebada soya, sorgo, ajonjoli, trigo, pepita, chicharo.

**Figure 8: Distribution of the change in crop quantities, 2007-2011, for rich common property households**




Crop categories are as above.

For private households engaged in agriculture, the value per hectare of agricultural land has nearly doubled – from 5021 pesos (approximately $429 USD) to 9179 pesos (approximately $785 USD) per hectare. This change appears to be much larger for beneficiary private households, although the differences are not statistically significant. Private households also had decreases in their production of grains. We conclude that the change in value of agricultural output for private households is driven by the substitution of cash crops (mostly fruits) for grains. We do not see heterogeneity in this result across the income spectrum, but our sample size is probably too small to expect this.

Although there seems to have been no significant change in the amount of agricultural goods marketed, there appear to be some changes in *where* households market their agricultural production (Table 20). Some of these differences could be driven by discrepancies in baseline values, rather than trends which differ as a result of receiving the program. For example, in common property communities, we observe an increase in the fraction of goods sold within the community (approximately 6 percentage points). However, there was less sold within beneficiary communities than in non-beneficiaries in 2007. We also see a decrease in the fraction of goods sold in small markets outside of the

community for beneficiaries. Based on these results, one might infer that cash transfers coming from the program activate local markets, reducing the need to look for outside buyers. With regards to private households, there are not significant differences between beneficiaries and non-beneficiaries both in the baseline and in the year 2011. In general, it seems that over time beneficiary private properties increasingly sell their products in markets outside of their localities, but so so non-beneficiaries.

**Table 20: Location of sales of agricultural production: fraction in each category in each year**

| | Households in ejidos | | | Private households | | |
|---|---|---|---|---|---|---|
| **Year 2007** | Benef. | Non-benef. | Difference | Benef. | Non-benef. | Difference |
| **Market inside community/locality** | 0.265 | 0.310 | -0.045 | 0.286 | 0.111 | 0.175 |
| **Small market outside** | 0.133 | 0.209 | -0.077 | 0.071 | 0.056 | 0.016 |
| **Large market outside** | 0.094 | 0.093 | 0.001 | 0.286 | 0.222 | 0.063 |
| **Intermediary** | 0.409 | 0.380 | 0.029 | 0.286 | 0.556 | -0.270 |
| **Cooperative** | 0.094 | 0.000 | 0.094*** | 0.071 | 0.056 | 0.016 |
| **Mixed** | 0.006 | 0.008 | -0.002 | 0.000 | 0.000 | 0.000 |
| **Year 2011** | Benef. | Non-benef. | Difference | Benef. | Non-benef. | Difference |
| **Market inside community/locality** | 0.305 | 0.293 | 0.011 | 0.222 | 0.118 | 0.105 |
| **Small market outside** | 0.103 | 0.195 | -0.092* | 0.111 | 0.059 | 0.052 |
| **Large market outside** | 0.080 | 0.053 | 0.028 | 0.333 | 0.353 | -0.020 |
| **Intermediary** | 0.402 | 0.451 | -0.049 | 0.278 | 0.412 | -0.134 |
| **Cooperative** | 0.103 | 0.000 | 0.103*** | 0.056 | 0.059 | -0.003 |
| **Mixed** | 0.006 | 0.008 | -0.002 | 0.000 | 0.000 | 0.000 |

As mentioned above, a concern about PES programs in general is that they might shift deforestation from one area to another within a property, creating new deforestation "slippage" or "leakage." [14] However, when we look at whether people are clearing land for crops, from either forest or secondary vegetation (Table 21), we see no significant differences between beneficiaries and non-beneficiaries living in common property communities. When we compare beneficiary communities according to how funds are allocated at the community level, we do see that households in communities that provide lump-sum transfers

[14] More than 90% of households living in common property communities have their production activities (agriculture, forestry, and livestock) inside the boundaries of the community and there are no significant differences in location both over time and between beneficiaries and non-beneficiaries.

clear significantly more land for crops from secondary vegetation (25%) than those without these transfers (15%) and these differences are mostly explained by households with land-use rights. It is possible that these numbers are explained by differences in agricultural systems by region, since most communities providing lump-sum transfers are located in the south east. However, since we observe this effect only in households with land-use rights within the south east region, it is also possible that transfers are being used by ejidatarios to expand their agricultural production or use land that was not previously used. For private households, more non-beneficiaries indicate that they cut big trees in order to cultivate crops (43%) when compared to beneficiaries (31%); however, this difference is not statistically significant.

**Table 21: Type of vegetation in the land cleaned before cultivation**

| **Common property communities** | | | |
|---|---|---|---|
| **Type of vegetation** | **Beneficiaries** | **Non-beneficiaries** | **Diff.** |
| Big trees | 0.066 | 0.047 | 0.019 |
| Secondary vegetation | 0.192 | 0.182 | 0.010 |
| Pasture | 0.040 | 0.043 | -0.002 |
| Land was recently cultivated | 0.756 | 0.738 | 0.018 |
| **Sample of beneficiaries** | **Lump-sum transfers** | **No lump-sum transfers** | **Diff.** |
| Big trees | 0.085 | 0.060 | 0.025 |
| Secondary vegetation | 0.254 | 0.150 | 0.104** |
| Pasture | 0.045 | 0.030 | 0.015 |
| Land was recently cultivated | 0.672 | 0.817 | -0.144*** |
| **Private households** | | | |
| **Type of vegetation** | **Beneficiaries** | **Non-beneficiaries** | **Diff.** |
| Big trees | 0.306 | 0.433 | -0.128 |
| Secondary vegetation | 0.194 | 0.133 | 0.061 |
| Pasture | 0.083 | 0.000 | 0.083 |
| Land was recently cultivated | 0.389 | 0.433 | -0.044 |

Note: Numbers reported in these tables are the proportion of households that reported each type of vegetation for any of the crops they cultivated in 2011. Since we are looking at the 5 most important crops cultivated by households, groups of households in each vegetation category are not mutually exclusive and this is why the proportions don't necessarily add up to 1.

## Livestock production

We also examine changes in the number and location of livestock activities (Table 22). It is difficult to calculate animals per area in the communities where animals tend to walk freely around the community. For this reason, when calculating land areas used for cattle in the ejidos, we used the area indicated as pasture for households that stated this number. For households that indicated that their

animals grazed throughout the ejido, we used the area of total ejidal land per ejidatario as a proxy. The baseline numbers of total animals per household are similar for beneficiary and non-beneficiary households but slightly higher for total cattle in non-beneficiary households. In the baseline, a larger proportion of non-beneficiaries indicated owning cattle. Private beneficiary households also report lower total area used for livestock activities (119 ha vs. 180 ha in 2011) than non-beneficiaries as well as somewhat lower numbers of total cattle. Looking at differences in differences across time to assess impacts, we find that the changes in livestock ownership and grazing induced by the program are small but positive – beneficiaries increase their likelihood of owning cattle by 4 percentage points (an increase of about 18 percent), and the total number of animals owned by those owning cattle increases by nearly 3 animals. It is possible that this reflects an asset increase due to the program, since livestock may represent a type of savings bank for households.

The ratios of cattle to grazing land are decreasing over time in beneficiary households and remaining constant in non-beneficiary households, with starting values of 5 and 3 animals per hectare, respectively. We should note that these ratios are high when compared to the average ratios suggested as appropriate for the sustainable use of resources in Mexico (0.084)[15] and there is also significant dispersion across households.[16] Our calculation, which attributes an equal amount of land to each ejidal household when animals are indicate to graze freely, however, may bias these numbers upwards.

[15] The average grazing land coefficient ("coeficiente de agostadero") for all states in Mexico is 11.93 hectares per animal unit. This coefficient measures the ratio of area to animal units that is needed for livestock activities to be productive and sustainable in terms of the use of natural resources (COTECOCA, 2009).

[16] For households in common property communities, the median in 2011 is 0.95, the maximum value is 2,444.87 and the minimum value is 0.01. For private households, the median in 2011 is 0.33, the maximum value is 4.88 and the minimum value is 0.01.

## Table 22: Livestock activities characteristics for households

**Common property communities**

| Livestock activities characteristics | Beneficiaries | Non-beneficiaries | Diff. |
|---|---|---|---|
| Area of total ejido land per household | 84.58 | 116.7 | -32.1 |
| Total large animals 2007 | 11.773 | 11.408 | 0.365 |
| Total large animals 2011 | 13.879 | 10.694 | 3.185 |
| **Change total animals** | **2.106** | **-0.715** | **2.820** |
| Has cattle in 2007 | 0.22 | 0.268 | -0.045 |
| Has cattle in 2011 | 0.26 | 0.27 | -0.006 |
| **Change in has cattle** | **0.04** | **-0.002** | **0.039**** |
| Total cattle 2007 (average for those with cattle) | 10.18 | 14.76 | -4.58 |
| Total cattle 2011 (average for those with cattle) | 11.21 | 13.08 | -1.87 |
| **Change total cattle** | **1.02** | **-1.67** | **2.71*** |
| Animals walk freely around community 2007 | 0.38 | 0.49 | -.144** |
| Animals walk freely around community 2011 | 0.359 | 0.488 | -.128** |
| **Change animals walk freely in community** | **-0.03** | **-0.01** | **-0.02** |
| Cattle / land per ejidatario 2007 | 5.39 | 2.62 | 2.76 |
| Cattle / land per ejidatario 2011 | 2.67 | 2.46 | .20 |
| **Change cattle / land per ejidatario** | **-1.66** | **.01** | **-1.66** |
| Value per hectare of grazing land for cattle 2007 | 11999.69 | 7206.13 | 4793.56 |
| Value per hectare of grazing land for cattle 2011 | 7293.362 | 6681.13 | 612.23 |
| **Change value per hectare of grazing land for cattle** | **-4706** | **-524** | **-4181** |

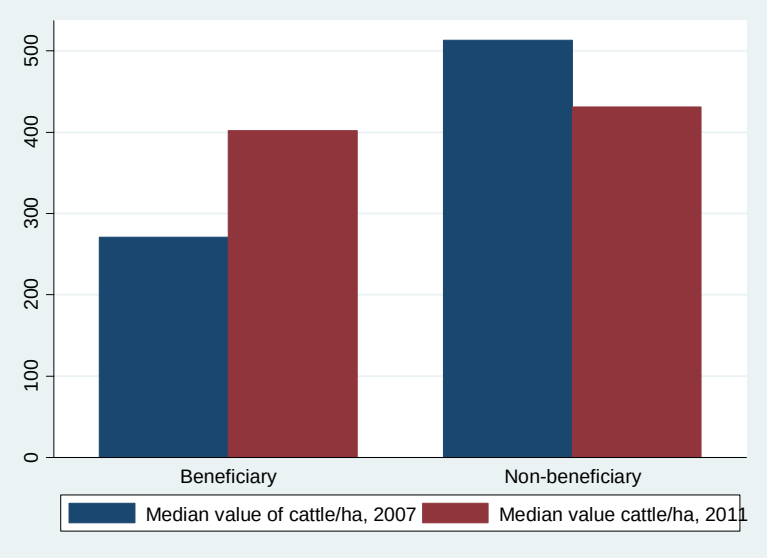
Note: Value per hectare considers all households with cattle and uses the median price observed for cattle in the sample for all of them.

**Private households**

| Livestock activities characteristics | Beneficiaries | Non-beneficiaries | Diff. |
|---|---|---|---|
| Area for livestock activities 2007 | 155.669 | 227.808 | -72.139 |
| Area for livestock activities 2011 | 118.852 | 180.467 | -61.615 |
| **Change area livestock** | **-42.431** | **-35.538** | **-6.892** |
| Total animals 2007 | 51.328 | 36.596 | 14.731 |
| Total animals 2011 | 54.443 | 34.544 | 19.899 |
| **Change total animals** | **3.115** | **-2.053** | **5.167** |
| Has cattle in 2007 | 0.36 | 0.43 | -0.08 |
| Has cattle in 2011 | 0.36 | 0.38 | -0.03 |
| **Change in has cattle** | **0** | **-0.05** | **0.05** |
| Total cattle 2007 (average for those with cattle) | 47.0 | 50.2 | -3.19 |
| Total cattle 2011 (average for those with cattle) | 38.0 | 46.1 | -8.11 |
| **Change total cattle** | **-8.96** | **-4.03** | **-4.92** |
| Cattle / grazing land per household 2007 | 2.44 | 1.85 | .58 |
| Cattle / grazing land per household 2011 | 2.71 | 1.06 | 1.64 |
| **Change cattle / grazing land per household** | **.31** | **-.07** | **.39** |
| Value per hectare of grazing land for cattle 2007 | 13982.15 | 11120.77 | 2861.38 |
| Value per hectare of grazing land for cattle 2011 | 15785.40 | 6463.11 | 9295.29 |
| **Change value per hectare of forest land for cattle** | **2440.96** | **-123.16** | **2564.11** |

Similar to our analysis of agricultural production, we also calculate the value per hectare (or revenue per hectare) of land used to raise cattle as the price of cattle times the quantity divided by the land available. These values consider all cattle available and not only what is sold. [17] Among common property households, we find that non-beneficiaries have a lower value per hectare of land used to raise cattle, but the changes are not significantly different in the baseline or over time between beneficiaries and non-beneficiaries. The estimates are extremely imprecise due to the large variation in the data. In order to minimize the impact of outliers, we consider in Figure 9 the medians of these values. The figure shows that there are some differences between beneficiaries and non-beneficiaries in the baseline – beneficiaries tend to have had a lower value per hectare of cattle in 2007. However, while this value decreased for non-beneficiaries, it went up for beneficiaries.

**Figure 9: Median value of cattle per hectare in beneficiary and non-beneficiary communities**




[17] Since not all households sell their cattle, these values were calculated considering the median price of cattle in the sample and multiplying this value by the number of cattle each household has. We then divided this number by the area of total land available for each ejidatario. This area is obtained by dividing the total area of land in the community over the total number of ejidatario households in the community.

Among private property households, it is a much simpler task to assess area dedicated to livestock. Here we find that both beneficiaries and non-beneficiaries decreased the land used for livestock over time while the total numbers of livestock are similar across time. This again suggests increasing intensification of livestock production. The value per hectare of available land is lower for private households as are the ratios of livestock to total land area. We do not find increases in the value per hectare for either beneficiary or non-beneficiary private households—both decline a bit over time as the number of animals and cattle kept by these households decline. The similarity in trends suggests the program is not having a significant impact on livestock production by private property households.

We consider next where livestock are grazed within properties. The program does not seem to have changed where livestock are grazed within ejidos – between 87 and 93% of households with cattle graze these animals within the ejido, and this was not significantly changed by the program. This is reassuring as a potential objection to the program is that it would limit access to communal grazing lands by community members, hurting livelihoods.

There are, however, significant differences in the changes in the location of livestock activities for private households. After enrolling in the program many beneficiaries do move their livestock activities from land enrolled in the PSAH to land that is outside but close to these areas. This indicates that the program is working as intended to reduce grazing within hydrological services areas. However, the shift may put more pressure on other areas that are close to the enrolled land.

**Table 23: Location of livestock activities**
**Common property communities**

| Location of cattle | Beneficiaries | Non-beneficiaries | Diff. |
|---|---|---|---|
| Inside ejido 2007 | 0.902 | 0.923 | -0.020 |
| Inside ejido 2011 | 0.870 | 0.915 | -0.045 |
| **Change inside 2011-2007** | **-0.018** | **-0.016** | **-0.002** |
| Outside close 2007 | 0.075 | 0.042 | 0.033 |
| Outside close 2011 | 0.084 | 0.050 | 0.035 |
| **Change outside close 2011-2007** | **0.009** | **0.016** | **-0.007** |
| Outside far 2007 | 0.023 | 0.035 | -0.013 |
| Outside far 2011 | 0.045 | 0.035 | 0.010 |
| **Change outside far 2011-2007** | **0.009** | **0.000** | **0.009** |

**Private households**

| Location of cattle | Beneficiaries | Non-beneficiaries | Diff. |
|---|---|---|---|
| Inside PSAH area 2007 | 0.318 | 0.480 | -0.162 |
| Inside PSAH area 2011 | 0.091 | 0.545 | -0.455*** |
| **Change inside 2011-2007** | **-0.158** | **0.048** | **-0.206*** |
| Outside PSAH area but close 2007 | 0.364 | 0.280 | 0.084 |
| Outside PSAH area but close 2011 | 0.545 | 0.182 | 0.364* |
| **Change outside close 2011-2007** | **0.211** | **-0.048** | **0.258*** |
| Outside PSAH area and far 2007 | 0.318 | 0.240 | 0.078 |
| Outside PSAH area and far 2011 | 0.364 | 0.273 | 0.091 |
| **Change outside far 2011-2007** | **-0.053** | **0.000** | **-0.053** |

Note: Numbers reported in these tables are the proportion of households that indicate they have their livestock activities in that particular location.

### Investments and credit constraints

It is also important to consider potential investment in inputs which might provide profits in the near to long-term. With regards to these uses of household funds, we do not observe significant differences in the overall proportions of households who reported investing in agricultural equipment, livestock, housing, education, or new businesses between beneficiaries and non-beneficiaries (results available upon request). However, the program does appear to induce *new* investment in the sense that households which were not investing at baseline are more likely to invest if they are in beneficiary communities. For example, among those without investment in new agricultural crops, beneficiary households were nearly 4 percentage points more likely to investment (more than doubling the probability among non-beneficiaries). In addition, they were 4 percentage points more likely to invest in livestock infrastructure, relatively to non-beneficiary investment of 6

percent – implying an increase of 67 percent in the likelihood of new investment as a result of the program.

When we consider heterogeneity in investment by type of transfer (lump sum versus other), we observe that direct transfers from the program nearly double the probability that ejidatarios will invest in livestock infrastructure, and increase the likely of (new) housing investment by 12 percentage points (39 percent). Finally, when we consider heterogeneity across space in ejido investment, households living far from urban centers show a significant increase in the propensity to invest in health as a result of the program, although these households also had a much higher propensity to do so in the baseline. Private households show no significant changes in investment, even when disaggregated by distance to urban area. Overall, it appears that the most severely credit constrained households (those in common properties, in remote areas, and with little investment in the baseline) do experience significant and positive investment impacts from the program.

Finally, when we look at households' demand for credit, we find that in private households, fewer beneficiary households requested a loan in the past 12 months (24% of beneficiaries versus 33% of non-beneficiaries). Of those who request loans, the vast majority (94%, receive them), and the main sources are private banks or the Caja Popular. One interpretation of this is that beneficiaries need fewer loans, since they have income from the program to supplement their liquidity. This would be a positive impact of the program since it is likely to lower households' overall borrowing costs. An alternative hypothesis is that beneficiaries have less access to credit and therefore do not request loans, but we find that 74% of the beneficiaries believed that a loan would have been easy to get if they had wanted one, compared to 58% of the non-beneficiaries. 75% of beneficiaries who did not request loans also said that they didn't need one during the past 12 months, compared to 63 percent of non-beneficiaries.

In common property households, 27 percent of households ask for a loan in the past 12 months, and this difference was not significant between beneficiaries and non-beneficiaries. 96% of those common property households requesting loans receive one, though most of these come from family or friends. It appears that the program funds help replace formal credit for private households, but do not affecting borrowing behavior of common property households.

**SUMMARY**

This section of the report shows that the program has not significantly affected agriculture or livestock livelihoods and may have had some positive impacts on credit constraints. The majority of beneficiaries originally employed in agriculture, livestock or forestry remain employed in those categories and the overall percentages of people employed in each sector are very similar across time. Production of food crops, including staple crops, does not decrease on

average or show different general trends between beneficiaries and non-beneficiaries, suggesting that the program does not compromise food security. Both beneficiaries and non-beneficiaries show intensification of agriculture and rising value per ha of production across time. We do not see significant differences between beneficiaries and non-beneficiaries in whether agricultural products are sold outside of the community although there is some evidence that common property beneficiary households are selling more within the community; it is possible that the cash payments have helped to activate local markets. Reported prevalence of land clearing for cultivation is also not significantly different across beneficiaries and non-beneficiaries.

Livestock production trends are generally not significantly different between beneficiary and non-beneficiary households, again results that are reassuring from a livelihoods perspective. We do however see an increase in the average number of livestock owned by beneficiary common property households, possibly indicating a positive impact on assets not captured by the previous analysis. Private property households overall showed decreases in livestock production and land used—but trends were very similar across beneficiaries and non-beneficiaries.

With respect to investment, we find tentative evidence that the program may have relaxed credit constraints for some households. We see less borrowing among private property beneficiaries and we see some increased production of cash crops among poor common property households. Common property households who were not investing in new crops or livestock infrastructure at baseline are more likely to invest in 2011 if they were beneficiaries. A related investment effect is the evidence that the program appears to have helped ejidatario households receiving lump-sum transfers and private property households to keep their kids in school longer, an investment likely to pay off in the future.

Although the lack of substantial increases in production or investment is somewhat disappointing from a poverty alleviation/ income generation standpoint, it is reassuring that trends are generally similar between beneficiaries and non-beneficiaries. This suggests the program has largely preserved livelihood strategies that would have been adopted in the absence of the program. It is also reassuring in terms of possible concerns about substitution slippage or “leakage” (Alix-Garcia et al. 2011) which could have occurred if cash payments encouraged expansion of production that required new clearing on other parts of the same properties.

## Section 5: Forest management activities

In this section we assess the impacts that the program has had on forest management, as measured by our survey data. This analysis complements Part III of the report in which we directly assess environmental impact using remote sensing methodologies. Changes in forest management are likely to lead to changes in forest quality or structure which may not be observable with the satellite analysis. The results in this section are from questions regarding participation in workshops and forest management activities at both the household and the ejido level.

### Forest management skills

One of the original motivations for including dedicated funding for technical assistance as part of the payments to program participants was precisely to provide training and skills building in sustainable forest planning and management for the long term. The program has clearly been successful in achieving this goal. As shown in Table 24, beneficiary communities have participated in a significantly larger number of forest-related training workshops relative to non-beneficiaries. In most cases, the proportion of households having received training between 2007 and 2011 is close to twice as high in beneficiary communities, and the number of trainings is generally significantly higher. Similar trends are also seen in private properties.

**Table 24: Training in forest management activities**

| Forest management activities | Proportion of households that received training 2007-2011 | | | Average number of times households received training 2007-2011 | | |
|---|---|---|---|---|---|---|
| | Benef | Non-benef | Diff. | Benef | Non-benef | Diff. |
| Firebreaks | 0.480 | 0.208 | 0.272*** | 3.348 | 2.505 | 0.843* |
| Fire control and combat | 0.408 | 0.202 | 0.205*** | 3.220 | 1.943 | 1.277*** |
| Fences | 0.233 | 0.066 | 0.167*** | 2.857 | 2.806 | 0.051 |
| Pest control | 0.221 | 0.059 | 0.163*** | 2.984 | 7.069 | -4.085* |
| Forest nurseries | 0.196 | 0.072 | 0.124*** | 2.696 | 2.400 | 0.296 |
| Reforestation | 0.460 | 0.210 | 0.250*** | 3.375 | 2.238 | 1.137* |
| Thinning trees | 0.263 | 0.091 | 0.173*** | 2.510 | 2.208 | 0.302 |
| Cleaning forest | 0.319 | 0.100 | 0.219*** | 2.955 | 2.226 | 0.729* |
| Forest patrols | 0.280 | 0.066 | 0.214*** | 3.383 | 2.875 | 0.508 |
| Soil conservation | 0.341 | 0.168 | 0.172*** | 3.069 | 2.186 | 0.883* |
| Water collection | 0.200 | 0.081 | 0.118*** | 2.833 | 2.308 | 0.526 |
| Environmental services | 0.322 | 0.079 | 0.243*** | 3.420 | 2.216 | 1.204* |
| Access ES markets | 0.124 | 0.042 | 0.083*** | 2.957 | 2.500 | 0.457 |

It is likely that the program is impacting the development of sustainable forest management skills and a knowledge base within these sites that will effect forest health and productivity well past the PSAH program's end date. Case study interviewees at all levels mentioned that program funds are often used to purchase the equipment that increases the ability of beneficiaries to sustainably manage their forest. This investment in physical capital will likely continue to positively impact the ability of these beneficiaries to protect their forest even after the program has finished.

**Forest management activities**

In evaluating actual time worked in the forest, we first consider leader responses, which are given in the number of jornadas (work days) reported for a particular activity in 2011. If activities were clearly funded by other CONAFOR programs, rather than the PSAH, those activities were subtracted from the totals reported ( Table 25). While it is clear that non-beneficiaries spend a significant amount of time in forest management (on average 119 jornadas per year), beneficiaries spend significantly more time – nearly 278 jornadas. These increases are particularly large (and mostly significant) for forest patrols, firebreaks, fire prevention, and constructuring fences. It seems that the program changes the amount of time spent in the forest as a whole, as well as affecting the composition of activities.

**Table 25: Jornadas spent in different forest management activities in 2011, common properties**

| Number of days worked in different forest management activities | Mean beneficiaries | Mean non-beneficiaries | Difference |
|---|---|---|---|
| Firebreaks | 37.138 | 2.906 | 34.232 |
| Fire prevention and combat | 24.431 | 5.679 | 18.752* |
| Constructing fences | 14.983 | 3.434 | 11.549* |
| Pest control | 18.017 | 0.811 | 17.206 |
| Forests nurseries | 1.103 | 0.849 | 0.254 |
| Reforestation | 16.414 | 20.019 | -3.605 |
| Thinning trees | 17.138 | 6.132 | 11.006 |
| Forest cleaning after use | 16.448 | 4.887 | 11.561 |
| Forest patrols | 202.569 | 60.189 | 142.380 |
| Soil conservation | 30.207 | 7.208 | 22.999* |
| Water collection | 17.448 | 6.547 | 10.901 |
| **Total days worked in 2011** | 395.897 | 118.660 | 277.236* |

Note: Excludes days worked in activities that were financed by other CONAFOR programs.

The program has also induced large changes in forest management activities in private households. As shown in Table 26, on average, beneficiaries applied 182 more jornadas to their forest than non-beneficiaries in 2011. The largest changes in activities were in forest patrols and firebreaks.

**Table 26: Jornadas spent in different forest management activities in 2011, private properties**

| Number of days worked in forest management activities in 2011 | Mean beneficiaries | Mean non-beneficiaries | Difference |
|---|---|---|---|
| Firebreaks | 37.705 | 7.158 | 30.547** |
| Fire prevention and combat | 12.459 | 3.754 | 8.705 |
| Constructing fences | 19.049 | 10.842 | 8.207 |
| Pest control | 9.443 | 5.123 | 4.320 |
| Forests nurseries | 7.279 | 0.035 | 7.244 |
| Reforestation | 9.574 | 5.193 | 4.381 |
| Thinning trees | 5.770 | 4.105 | 1.665 |
| Forest cleaning after use | 20.574 | 1.333 | 19.240* |
| Forest patrols | 104.295 | 28.123 | 76.172*** |
| Soil conservation | 18.607 | 1.807 | 16.800** |
| Water collection | 5.918 | 1.211 | 4.708 |
| **Total days worked in FMA 2011** | 250.672 | 68.684 | 181.988*** |

Note: Excludes days worked in activities that were financed by other CONAFOR programs.

When we requested similar information from households within ejidos, we found that their estimates of time spent on particular forest management activities were much less than that of the leaders (Table 27) although the trends between the groups are similar. The household level responses indicate the largest increase in time dedicated to the forest, and large impacts on time dedicated to fire prevention and patrol activities. This is consistent with what the leaders report, although the magnitudes are smaller. Some of this difference may be explained by a skewed distribution of forest management activities among households—the system of rotating responsibilities for community activities means that some households will disproportionately contribute to forest management in any given year but might not have been surveyed in the household sample. In addition, it is possible that multiple activities take place on particular days, making it difficult for leaders to keep track of numbers of days for specific activities. We conclude from these divergent reports that the program has indeed increased time spent in the forest, and that much of this impact seems to occur around defensive mechanisms.

**Table 27: Days work in different activities reported by ejido households**

| Days worked in forest management activities in 2011 | Mean beneficiaries | Mean non-beneficiaries | Difference |
|---|---|---|---|
| Firebreaks | 7.928 | 11.831 | -3.903 |
| Fire prevention and combat | 7.030 | 4.225 | 2.805 |
| Constructing fences | 8.430 | 8.039 | 0.391 |
| Pest control | 4.901 | 3.490 | 1.411 |
| Forests nurseries | 7.684 | 52.351 | -44.667* |
| Reforestation | 5.842 | 12.430 | -6.588 |
| Thinning trees | 6.488 | 8.992 | -2.504 |
| Forest cleaning after use | 5.367 | 7.320 | -1.954 |
| Forest patrols | 10.799 | 6.423 | 4.376 |
| Soil conservation | 12.032 | 12.922 | -0.890 |
| Water collection | 4.606 | 7.126 | -2.520 |
| **Total days worked 2011** | 25.552 | 22.903 | 2.649 |

Note: Calculations were done with a subsample that was matched based on baseline participation decisions in forest management activities. The averages reported here consider only those households that report positive days of work.

Despite its lack of correspondence with the leaders' reports, one might take the ejido households responses as a lower-bound on the programs impacts on forest labor allocation. In addition, one of the advantages of the ejido household survey is that we were able to track changes both over time and across program status. This is possible because we requested retrospective data on labor allocation from households, and it enables us to better measure the "true" impact of the program on forest management activities. Table 28 shows a comparison between "matched" households in beneficiary and non-beneficiary ejidos. Note that both types of communities were quite active in the forest even before beginning the program in 2007. In addition, between 2007 and 2011, both increased the amount of time spent in the forest. The program impact is measured by the differential size of the increase in beneficiary versus non-beneficiary communities. For example, when we consider total days in the forest, if we limited ourselves to beneficiaries (a before-after approach), we would attribute 11 extra forest days to the program. If we were to consider just the differences between beneficiaries and non-beneficiaries in 2011, we would attribute 4.02 extra days of forest effort. However, non-beneficiaries also increase their engagement with the forest, even in the absence of the program, though this increase is differentially smaller. Subtracting out this time trend, we observe an estimated impact of 3.7 days in the forest, with most of that impact coming from an increase in paid work days.

**Table 28: Program impact on total forest management activities in ejidos**

| Days worked in forest management activities | Mean beneficiaries | Mean non-beneficiaries | Difference |
|---|---|---|---|
| Days 2007 | 7.330 | 6.382 | 0.948 |
| Days 2011 | 18.675 | 13.248 | 5.426* |
| **Change days 2011-2007** | **11.345** | **6.867** | **4.478** |
| Days paid 2007 | 3.771 | 3.563 | 0.208 |
| Days paid 2011 | 12.565 | 8.907 | 3.657 |
| **Change days paid 2011-2007** | **8.794** | **5.344** | **3.450** |
| Days unpaid 2007 | 5.255 | 2.819 | 2.436 |
| Days unpaid 2011 | 7.876 | 4.929 | 2.947 |
| **Change days unpaid 2011-2007** | **2.621** | **2.110** | **0.511** |
| **Number of observations** | **457** | **427** | |

Another interesting aspect is that we find heterogeneity in the ejido results depending upon how the money is distributed. Total forest labor increases (relative to non-beneficiaries) on average by 7 days in villages which give lump sum transfers rather than wage payments for forest work, with 5.1 of these days coming from unpaid labor. The total increase in labor for communities not giving lump sum transfers is 3.3, and in these villages there is a large increase in paid days of labor (4.4) and a decrease in days of unpaid labor (1.7) relative to non-beneficiaries. The choice of how to distribute funds within an ejido reflects, of course, many other features of the community, including how participative the community members are. While we cannot at this point attribute causality to this mechanism, it seems important to note that in some situations, the choice to use funds to finance wage labor in the forest may act to displace voluntary community service.

### Access to forest

An additional expected impact of the program is that communities may put in place additional rules governing forest use. These may be beneficial in terms of helping to protect environmental services from the forest, but may also come at some cost to those who are dependent on forest products. Table 29 reports perceptions about forest rules and access to forest coming from community leaders and households. We can see that a higher proportion of leaders in beneficiary communities (0.79) do indicate they have rules for forest use in 2011 when compared to non-beneficiaries (0.70), although the differences are not statistically significant. There are, however, some significant differences when we look changes in rules over time. A higher proportion of leaders in beneficiary communities reported that they have more rules about forest use in 2011 when compared to 2007 (0.33 vs. 0.09). This indicates that beneficiary communities may have been more likely to adopt new rules governing forest management as a

result of the program. We also find that significantly more beneficiary communities participating in the program do forest patrols in 2011 (.95 vs .70).

Have these rules come at a large cost in terms of access? When we look at households' perceptions, we do see a marginally significant difference: 58% of households living in beneficiary communities feel that their access to the forest is more difficult now when compared their access 4 years ago, while 55% of non-beneficiary households feel this way. Although this indicates concern on the part of many households, it is important to note that the trend between beneficiary and non-beneficiary households is not very different in size. This suggests that the increasing difficulty of accessing forest over time is something happening in both beneficiary and non-beneficiary communities and thus may not be attributable to the program.

**Table 29: Perceptions about forest rules and access to forest**

| Variables of forest access | Beneficiaries | Non-beneficiaries | Diff. |
|---|---|---|---|
| ***Community leaders' perceptions*** | | | |
| Have rules for forest use in 2011 | 0.793 | 0.698 | 0.095 |
| More rules for forest use in 2011 than 2007 | 0.333 | 0.086 | 0.248* |
| Same rules for forest use in 2011 than 2007 | 0.296 | 0.657 | -0.361** |
| Fewer rules for forest use in 2011 than 2007 | 0.370 | 0.257 | 0.113 |
| Have forest patrols in 2011 | 0.948 | 0.698 | 0.250*** |
| ***Households' perceptions (women's survey)*** | | | |
| More difficult access to forest in 2011 | 0.584 | 0.546 | 0.038* |
| No changes in access to forest | 0.311 | 0.347 | -0.035* |
| Easier access to forest in 2011 | 0.105 | 0.107 | -0.002 |

Note: Numbers reported in the table are the proportion of leaders or households that responded yes or positively to the specified categories. Information for beneficiaries corresponds to land enrolled in the program. For non-beneficiaries is the total area of forest in the community.

## SUMMARY

The program has clearly had a positive impact on forest management which is important for the protection of ecological services. It has increased training in forest management and activities devoted to forest management--such skill training is likely to have long term benefits that extend beyond the program, because the up-front cost of learning has been paid. In addition, the program has significantly increased the time spent in activities related to preventing forest disease and fire. The time dedicated to this work is likely to have long term benefits for forest health. Information about perceptions related to forest access shows that rules about forest use have increased over time but households in beneficiary communities are only 4% more likely than households in non-beneficiary communities to feel that it is more difficult to access the forest than in the past. These results are a clear indication that the program has been successful in promoting increased forest management activities.

## Section 6: Direct participation costs of program for applicants

This section summarizes the costs of both application for and implementation of the program. It uses information from both the leader surveys and the household level estimations of labor allocated to the program. The opportunity costs of the program, which might be from foregone agricultural or forestry production, have already been discussed and generally seem to be small. However, in general the application costs and participation costs seem to be large compared to the size of payments, particularly for smaller landholders.

**Application costs**

Survey participants were asked a variety of questions regarding the application process for the program, including who did the majority of the work, how much money was used to apply for the program, and the cost of application in terms of time. One shortcoming of our study is that we are unable to compare these costs to the costs of applying for other federal programs, hence we cannot assess the PSAH application costs relative to similar programs within Mexico (or abroad). Since our survey is uniquely composed of program applicants, we can compare the effort put into application by both beneficiaries and non-beneficiaries.

On average, applicants apply more than once before receiving the program, and non-beneficiaries apply more frequently than beneficiaries. For ejidos, non-beneficiaries applied 1.9 times and beneficiaries 1.6. For private households, these numbers are 1.7 and 1.4, respectively, and the difference is statistically significant. For communities who successfully apply for program benefits, the majority of the application work was done by an intermediary (Table 30). Non-beneficiary communities (unsuccessful applicants) tend to have done more of the work themselves. Interestingly, for private properties this is reversed--successful applicants tend to have done more of the work themselves.

Successful applicants from common properties tend to have spent significantly more time acquiring the relevant documents to apply for the program – they spent, on average 109 days collecting this information, relative to non-beneficiaries, who spend 35 days on average. Private households spend significantly less time than ejidos collecting this information, which is not unexpected given the complications of decision-making in common properties. On average, they spend between 15 (beneficiaries) and 18 (non-beneficiaries) days collecting information required for the application, with no significant difference between successful and unsuccessful applicants. In both cases, the number of days required to complete the application is quite large – two work weeks for private beneficiaries, and considerably more for common property communities. At the same time, these application costs are relatively small as a percentage of the overall payments across 5 years. If we value this time at the

minimum wage, these numbers constitute only 0.49% and 0.36% of total payments to private and common property beneficiaries, respectively.[18]

**Table 30: Who did most of the work during the application process?**

| | Beneficiary | Non-beneficiary | Total |
|---|---|---|---|
| **Ejidos** | | | |
| Does not know | 0 | 3.773585 | 1.834862 |
| Community members | 39.28571 | 54.71698 | 46.78899 |
| Intermediary | 53.57143 | 35.84906 | 44.95413 |
| CONAFOR employees | 7.142857 | 5.660377 | 6.422018 |
| Total | 100 | 100 | 100 |
| **Private properties** | | | |
| Household member | 68.85246 | 42.10526 | 55.9322 |
| Intermediary | 26.22951 | 54.38596 | 39.83051 |
| CONAFOR employees | 4.918033 | 3.508772 | 4.237288 |
| Total | 100 | 100 | 100 |

Note: Column percentages are reported

During the application phase, a considerable amount of money is also spent on payments to intermediaries and community members, travel and documentation. Summaries are provided in Table 31. A sum of the mean amounts spent on each item indicates total payments for successful applicants on the order of 4870 pesos for communities and 1997 pesos for private properties. However, these are again relatively small percentages of the total payments: 0.28% for common properties and 1.12 % for private properties.

In addition, applicants make a significant number of trips to CONAFOR offices during the application process – common property applicants averaged 3.5 visits (with no significant difference between successful and unsuccessful applicants), private beneficiaries averaged 3 trips and non-beneficiaries 2 (difference statistically insignificant). Finally, common properties incur the additional time cost of holding community assemblies to discuss application to the program. Applicants average nearly 3 such assemblies, with no significant difference between beneficiaries and non-beneficiaries.

[18] To do this calculation we consider the daily minimum wage reported by CONASAMI for the whole country for 2011, which is 58.1 pesos. Program payments exclude those given for technical assistance. The average payment for the 5 years for common property communities is 17,762,835 pesos and for private households is 178,880 pesos.

**Table 31: Payments during application process**

| | Mean Beneficiaries | Mean Non-beneficiaries | Difference |
|---|---|---|---|
| **Common properties** | | | |
| Payments to intermediary | 3240.741 | 678.431 | 2562.309 |
| Payments to community members | 181.481 | 215.294 | -33.813 |
| Payments to obtain documents | 491.667 | 254.408 | 237.259 |
| Payments to CONAFOR employees | 0.000 | 0.000 | 0.000 |
| Payments for trips and travel expenses | 956.379 | 624.151 | 332.228 |
| TOTAL | 4870.3 | 1772.3 | 3098.0 |
| **Private households** | | | |
| Payments to intermediary | 1352.459 | 792.982 | 559.477 |
| Payments to obtain documents | 119.754 | 208.421 | -88.667 |
| Payments to CONAFOR employees | 0.000 | 87.719 | -87.719 |
| Payments for trips and copies | 410.000 | 435.000 | -25.000 |
| Payments for a topographer | 65.574 | 0.000 | 65.574 |
| Payments to an association | 49.180 | 0.000 | 49.180 |
| TOTAL | 1997.0 | 1524.1 | 472.8 |

**Implementation costs**

The calculation of the costs of program implementation is fraught with complications, particularly the cost of labor used in implementing the program (see below). Here we discuss approximations for the costs of technical assistance, materials, and labor used in implementation of the PSAH. A large percentage of beneficiaries receive technical assistance to implement the PSAH – 88 and 87 percent for common and private property beneficiaries, respectively. On average, leaders report these payments to be 186,949 pesos, or 51 percent of the average *yearly* common property payment, though of course if we take into account total program benefits it is considerably lower. For private households, survey participants report spending 33,772 pesos on these payments, which is almost equivalent to the average yearly PSAH payment for private properties, which is 35,600 pesos.

Calculating the labor costs of program implementation is very difficult as labor may be valued differently depending on the alternative opportunities available to households. To make an estimate that can be compared to the payment amounts, we value labor using reported wage values within the community. In cases where all wages are unpaid, we use wage values for neighboring communities to estimate reasonable rates. Both through the survey and through CONAFOR, we currently have information on the overlap of our

surveyed properties with other CONAFOR programs. In some calculations, we are therefore able to assume that costs for activities associated with these programs (reforestation, for example), are not being paid out of PSAH funds.

Here we report only "induced" labor – that is, the extra forest labor resulting from the program (the difference between beneficiaries and non-beneficiaries). We report estimates with and without considering other CONAFOR programs, and using both leader and household reports (Table 32 ). Beginning with ejidos, we observe that the ratio of labor costs to benefits has a tremendous range, from a minimum of .01 to a maximum of 0.83. The estimates derived from days worked reported by ejido leaders are quite high: counting all labor, and excluding from the calculation activities covered by other CONAFOR programs, the median ratio of labor to payments is 0.75. Keep in mind, however, that these calculations also include unpaid labor (faenas) valued at the minimum wage. It also may very well not be the case that individuals place this exact value on their time. The median ratio of induced paid labor to program yearly payments, taking into account participation in other CONAFOR programs, is 0.02. The household ejido data suggests that between 13 and 20 percent of program payments can be considered compensation for labor (20 coming from the calculation which excludes activities paid for by other CONAFOR programs, and 13 without adjustment from additional CONAFOR programs[19]). When we factor out "additional" labor (using the differences over time reported by households), we observe that between 6 and 7 percent of payments can be considered as compensation for this activity.

Finally, the labor paid for by private participants exceeds the program payments. However, it is important to note that even non-beneficiaries spend a considerable amount of money each year on hiring labor to take care of the forest – for example, non-beneficiaries in 2011 average 45,879 pesos per year in paid forest maintenance labor. Beneficiaries averaged 156,454 pesos, implying that participating in the program increased labor expenditures by 110,575 pesos. Unlike ejidos, private households tend to hire in the majority of the labor used in the forest – over 90% of forest labor in private properties is paid.

[19] The percentages with the adjustment from additional CONAFOR programs are higher since we are also taking into account the participation of non-beneficiaries in other CONAFOR programs.

**Table 32: Labor costs to PSAH payment ratios**

| Labor calculation | Median/yearly PSAH payment |
|---|---|
| **Without using information about participation in other CONAFOR programs** | |
| Total Beneficiary – Non-beneficiary labor , 2011(Ejido leaders) | 0.833 |
| Paid Beneficiary – Non-beneficiary labor , 2011(Ejido leaders) | 0.015 |
| Total Beneficiary – Non-beneficiary labor , 2011(Ejido households) | 0.196 |
| (Total Beneficiary – Non-beneficiary labor , 2011) – (Total Beneficiary – Non-beneficiary labor , 2007) (Ejido households) | 0.077 |
| Total Beneficiary – Non-beneficiary labor , 2011(Private properties) | 1.104 |
| Paid Beneficiary – Non-beneficiary labor , 2011(Private properties) | 0.634 |
| **With information about participation in other CONAFOR programs** | |
| Total Beneficiary – Non-beneficiary labor , 2011(Ejido leaders) | 0.751 |
| Paid Beneficiary – Non-beneficiary labor , 2011(Ejido leaders) | 0.017 |
| Total Beneficiary – Non-beneficiary labor , 2011(Ejido households) | 0.133 |
| (Total Beneficiary – Non-beneficiary labor , 2011) – (Total Beneficiary – Non-beneficiary labor , 2007) (Ejido households) | 0.068 |
| Total Beneficiary – Non-beneficiary labor , 2011(Private properties) | 1.040 |
| Paid Beneficiary – Non-beneficiary labor , 2011(Private properties) | 0.486 |

Table 32 indicates a measure of economic or opportunity cost, since it considers all forest labor, whether paid or unpaid. We consider this the best reflection of the full labor cost of program implementation. However, we also engaged in one further calculation using the information from leaders that indicated to us in which activities PSAH funds were actually used. Table 33 calculates the total payments for activities which were indicated as financed with PSAH funds, relative to program payments. In this case, all of the calculations indicate that wage payments are not actually exceeding program transfers.

**Table 33: Actual payments for activities in beneficiary communities, relative to program payment**

| Labor calculation | Median/yearly PSAH payment |
|---|---|
| Total Beneficiary (Ejido leaders) | 0.631 |
| Paid Beneficiary (Ejido leaders) | 0.007 |
| Total Beneficiary, 2011(Ejido households) | 0.136 |
| (Total Beneficiary, 2011) – (Total Beneficiary , 2007) (Ejido households) | 0.054 |
| | |
| Total Beneficiary (Private properties) | 0.475 |
| Paid Beneficiary (Private properties) | 0.402 |

In summary, by most of the possible measures, the available surplus of the program beyond covering costs is quite small. This provides some explanation for the small average impact on assets observed in section 2.

One explanation for the increase in the labor dedicated to forest management activities by both ejido and private property beneficiaries to a cost beyond that covered by the PSAH payments is that, at least in some sites, there was a need and a desire to improve management practices but not the capital to do so or a strong motivation to conserve forests. In addition, in areas with tree species suitable for lumber, additional labor for forest management may pay off directly in the long run, as work to protect the forest against fires, logging by outsiders, pests or disease is an investment in future harvests. As one community leader in Chihuahua explained when asked why his ejido had chosen to enter the PSAH program:

> "It was precisely because of the high incidence of forest fires. You need to take care of your resource, no? To have funds given to you to take care of it, how wonderful. We had been [protecting it] ourselves but with money we obtained through timber harvest."

However, the results are consistent with other interview results in which several of the program participants complained that the management plans required under the program were too costly and too restrictive. It is important to consider that the Programa de Manejo de Mejores Practicas (PMPM), which the participants develop and which outlines the work that the participant will complete, does allow for quite a bit of flexibility and the majority of activities performed are optional under the rules of operation. As one state level CONAFOR employee put it:

> "The obligatory components of the PMPM do not require much money. To prevent changes in land use, that most likely you are not even using, how could that take much money? Nor to put up educational signs, nor preventing overgrazing? These are the required activities. And for the optional ones,

> [participants] are the ones who decide what they will do and what their lands need. It would be a little incongruous and pushy on our part to say, 'You know what, you are going to do this and that other thing.' When in reality we don't know what they need. I could tell them, "You are going to reforest 100 hectares," but really they would do better with fire breaks because they have problems with forest fires. But this is an optional activity and they themselves decide which they will do."

While the CONAFOR employee might be underestimating the actual costs of protecting and conserving forestland, it is true that many of the increased forest management are optional. This may indicate either that participants are using the program as a means of jump-starting self-motivated conservation efforts. In some cases it may also be that their adoption and execution of so many activities is due to misunderstanding about the rules of the program.

**SUMMARY**

Our survey data indicate considerable costs to applicants both from applying to the program and implementing forest management activities. Application costs are relatively small compared to the overall payments, but the full costs of additional labor used for implementation (if valued at the minimum wage) are large compared to overall payments. This indicates that the costs of participating in PES programs may deserve more attention. To date, most theoretical analysis of PES (including ours) has focused on the opportunity costs of possible forgone production, and opportunity cost has been used as a justification for setting payment amounts (Muñoz-Piña et al. 2008). However the costs of forest management as well as the transaction costs of enrolling and communicating with CONAFOR deserve additional study since they may in fact be larger than opportunity costs. It would be important for CONAFOR to find out more about why participating communities are undertaking multiple forest management activities, since it is possible that there are also significant benefits from these activities which are gained by communities and households.

## Section 7: Program perceptions

Both ejido leaders and private and ejidal households were asked a series of questions about program perceptions. This is important because even though quantitative results might indicate positive impacts of the program, beneficiaries could have a different view. This might impact their likelihood of applying in the future or their willingness to comply with the program rules.

**Knowledge of the program**

Beneficiaries, both private households and leaders , were generally aware of the program and relatively clear about its goals. For example, 98 percent of community leaders and 100 percent of private households knew about the program. This knowledge was generally less among ejido households, at around 60%. This is at least partially due to the fact that we interviewed both ejidatarios and non-ejidatarios – ejidatarios tended to be more knowledgeable regarding the program, with 68%, while only 43% of non-ejidatarios are familiar with the program. Despite having applied, non-beneficiaries were less aware of the program, particularly at the household level. 89 percent of leaders and 93 percent of private households interviewed claimed awareness, compared to only 23 percent of ejido households (with 28% of ejidatarios aware of the program).

The majority of the respondents in beneficiary communities were aware that the program was related to environmental preservation and protection of the forest, but not confident that they would "sell" environmental services after the program ended – only 40 of private households responded that this would be the case, with 10 and 7 percent of ejido leaders and households, respectively, responding affirmatively to this question. 60 percent of ejido leaders and 52 percent of ejido households could not identify a potential buyer of environmental services.

**Table 34: Beneficiary program perceptions (% yes)**

| | Leaders | Ejidos | Privados |
|---|---|---|---|
| Awareness of PSAH program | 98.28 | 59.73 | 100 |
| Knows PSAH tecnico | . | 43.12 | . |
| Community receives PSAH payments* | 98.28 | 57.55 | 100 |
| Household receives direct payments from PSAH Program | . | 26.85 | . |
| Community sells environmental services | 0 | 0.67 | . |
| Community will sell ES after program ends** | 10.34 | 7.21 | 29.51 |
| Agree with community's participation in PSAH program | . | 56.88 | . |
| PSAH program benefitted community*** | 93.1 | 56.38 | 96.72 |

Table 1.0: Questions for beneficiaries only across all three categories. Ejidos (% out of 596), Privados(% out of 61), Leaders (% out of 58).Note: "." = question not asked for this group.

## Perceived benefits of the program

Within common properties, leaders and households uniformly answered that the main program benefits were more income and/or employment for the community – in total 73 percent of leaders and 66 percent of households listed one of these two outcomes as the primary benefit from the program (Table 35). Private households were more likely to respond that the main program benefit was more forest conservation (42%), which was followed by more income (27%). When non-beneficiaries were asked what they thought the main expected benefits from the program might be, the pattern of answers was quite similar: ejido leaders and households largely believed more income/employment to be the primary benefit, and private households felt that the main benefit would be support for conserving the forest.

From the case study interviews we conducted, there appears to be a widespread belief amongst beneficiaries that program payments are intended to cover the labor necessary to manage their forest sustainably, *not* as a compensation for the opportunity costs of foregoing forest clearing for other productive use. This attitude seems to be reinforced by the requirements of the program for a sustainable forest management plan and a yearly monitored set of management activities.

**Table 35: Perceived program benefits by beneficiaries (% yes)**

| | Leaders | | Ejidos | | Privados | |
|---|---|---|---|---|---|---|
| Benefit | Primary | Secondary | Primary | Secondary | Primary | Secondary |
| Más ingreso para comunidad | 52.73 | 23.33 | 49.40 | 17.12 | 27.12 | 10.87 |
| Asistencia técnica para manejo de tierras y bosques | 1.82 | 6.67 | 3.01 | 6.16 | 10.17 | 8.70 |
| Mayor empleo | 20.00 | 6.67 | 16.57 | 6.16 | 1.69 | 4.35 |
| Mejor conservación bosque | 16.36 | 50.00 | 17.47 | 36.30 | 42.37 | 28.26 |
| Mayor acceso a nuevos negocios y proyectos productivos | 1.82 | 3.33 | 1.81 | 3.42 | 1.69 | 0.00 |
| Mayor dinero para manejo de bosques | 3.64 | 3.33 | 3.61 | 10.27 | 16.95 | 41.30 |
| Mejoras en cantidad y calidad del agua | 3.64 | 6.67 | 4.22 | 10.96 | 0.00 | 6.52 |
| Evitar tala y caceria | 0.00 | 0.00 | 0.00 | 3.42 | 0.00 | 0.00 |
| No sabe | 0.00 | 0.00 | 1.20 | 3.42 | 0.00 | 0.00 |
| Otro | 0.00 | 0.00 | 2.71 | 2.74 | 0.00 | 0.00 |

Hogares:The primary column lists percentages for each benefit category for 332 responses out of 596 surveys. The secondary benefit column has percentgaes based on 146 responses out of 596 surveys. Privados: The percentages are out of 59 primary responses for 59 benef surveys and 46 secondary responses for 59 benef surveys. Communtiy leaders: Primary 55/58 and Secondary 30/58.

Household interviewees in common properties were asked a series of questions above improvements in their communities between 2007 and 2011. Questions included infrastructural improvements (water, health services, schools, roads, etc.), and new businesses created. A summary of responses to these questions across beneficiary and non-beneficiary communities is summarized in Table 36. Although there are some differences across beneficiaries and non-beneficiaries, none of these is statistically significant.

**Table 36: Perceived improvements in communities, % improved or yes**

| | **Benef** | **Non-benef** | **Difference** |
|---|---|---|---|
| Access and quality of water | 24.24 | 31.87 | -7.63 |
| Health Services | 34.69 | 40.31 | -5.62 |
| Schools | 52.47 | 58.67 | -6.2 |
| Roads and Transportation | 50.84 | 53.8 | -2.96 |
| Community Center | 36.27 | 35.32 | 0.95 |
| New Businesses | 17.15 | 20 | -2.85 |

A large number of the common property community leaders interviewed for the case studies also listed increased employment as one of the primary benefits they believed the program delivered. They were primarily referring to the local employment generated by the direct use of the PSAH payments for the management activities required by the program, but a number also mentioned that *ejidatarios* were using the payment portion distributed to their household to hire greater numbers of agricultural laborers.

While most of these community leaders pointed out that the employment generated by the program will not create long term sources of employment, many mentioned that the payments provide them with a source of funding that they can use to enact local level poverty alleviation. They stated that the benefit is in providing a quick source of income accessible to more marginalized groups in the community. They explained that this type of work requires little pre-training and can be completed during the short periods when underemployed community members (i.e. teenagers, avencindados, and female heads of households) are not able to work in their other activities (e.g. agricultural labor, school). As an example, when asked about the impact of the program on generating paid employment in his community, a *comisariado* of an *ejido* in Chihuahua responded that:

> "Pues han sido bastante buenos ahí, porque se genera muchos empleos, por ejemplo; antes los ejidatarios se beneficiaban porque se trabajaba el bosque, tenían ellos derecho a –que le llamamos- a lotes de madera, ya fuera de 80, 100 pinos según los metros que te marcaran. Entonces, ahora ya se benefician los hijos, los nietos, hijos de avecindados, avecindados y todas las personas que están sobre el ejido."

Even in the case of private property holders, the program payments may have ripple effects in creating employment. A number of beneficiary private property holders interviewed for the case studies from various regions of the country cited generation of local sources of employment as a perceived benefit. As one private household shade coffee grower who had paid laborers to conduct the management required by the program said:

> "El impacto es bueno porque el derrame económico es hacia la gente que vive alrededor de su finca o cerca de su finca, en las pequeñas rancherías donde se saca la mano de obra para trabajar. Y entonces empieza haber derrame económico para la región, pero fue un recurso que viene de la parte federal inyectado a un programa, y esparcido en una población"

This effect in generating short term employment opportunities may be greater in sites distant from urban areas where paid employment is less available. As

reported in Section 3, we found that employment in forestry increased as a secondary activity for beneficiary common property households distant from urban areas. In beneficiary private households distant from urban areas we observed a significant increase in employment in off-farm activities.

**Future uses of enrolled land**

Finally, leaders and households were asked what they expected the enrolled land to be used for after the program payments expired. The most common responses were that they would like to enroll the land in another PSA program, and that the land would never be used. Another smaller but still sizable proportion of respondents indicated that the land might be used for productive activities – either agricultural, pastoral, or for wood extraction. These results are summarized in Table 37 below.

**Table 37: Primary and secondary use household will give to enrolled land once the PSAH program is over**

| Use | Leaders | | Ejido households | | Private households | |
|---|---|---|---|---|---|---|
| | Primary | Secondary | Primary | Secondary | Primary | Secondary |
| Will never use land | 32.14 | 19.05 | 27.06 | 31.63 | 6.56 | 8.33 |
| Will use for agricultural and livestock activities | 10.71 | 19.05 | 8.53 | 14.29 | 24.59 | 16.67 |
| Will extract wood forest products | 5.36 | 14.29 | 7.94 | 9.18 | 9.84 | 11.11 |
| Will extract non-wood forest products | 0 | 4.76 | 1.47 | 1.02 | 0 | 5.56 |
| Will be enrolled in PSAH or other program | 33.93 | 28.57 | 27.06 | 21.43 | 47.54 | 27.78 |
| Will sell environmental services | 3.57 | 0 | 1.47 | 3.06 | 6.56 | 25 |
| Other | 3.57 | 0 | 4.12 | 7.14 | 1.64 | 2.78 |
| Keep with conservation | 7.14 | 14.29 | 9.12 | 7.14 | 3.28 | 2.78 |
| Does not know | 3.57 | 0 | 13.24 | 5.1 | 0 | 0 |

Note that only a small number of respondents believe that they might be able to sell ecosystem services at some future point in time. Results from a related masters thesis by Baker and Rice (2012) provides some of the explanations for this response. In a set of in-depth interviews conducted with households who had participated in the survey in Oaxaca and Yucatán, Baker and Rice (2012) explored both beneficiaries' and non-beneficiary perceptions of the possibilities for selling the ecosystem services of their forest in greater detail. They found that interviewees in both states were skeptical that external buyers could be found for environmental services because of a previous history of indifference by external actors toward conservation. For instance, in Oaxaca, one

interviewee explained that conservation "doesn't matter to other people, because they don't live here and don't have the necessity that we have." Another expressed a sense of injustice that downstream users do not pay for upstream forest conservation. According to her, tourist developers downstream of her property had cut down trees and built hotels "without any vision for the future." She said, "We always fight, because if they are beneficiaries of the water, why don't they bring a load of trees to reforest?"

Baker and Rice (2012) further reported the following: "Eight Yucatecan respondents, all of whom were private property owners or beneficiary *ejidatarios*, mentioned potential non-governmental ES buyers. Of these eight responses, foreign investment was most commonly mentioned. One *ejidatario* leader explained that he would prefer to negotiate directly with international parties, because he would make more money without CONAFOR as an intermediary. Another Yucatecan *ejidatario* described the concept of a public good to justify why external parties should pay for forest conservation: just as people pay for roads and highways, they should also pay for the benefits of the forest. One private property owner in Yucatán described a civil association he formed with other landowners in order to create a nature reserve and solicit ES payments from external parties. He predicted that this group of producers would sell ecosystem services to domestic and international companies within three years. In order for markets to develop, he believed that PSAH beneficiaries must disseminate the idea that water has social value, and that conservation can mitigate climate change.

All five Oaxacan interviewees who perceived potential to engage in an ES market were private property owners. They typically cited non-governmental buyers, such as the World Wildlife Fund. The clear distinction of private property owner responses may be due to their higher education levels and external connectivity, which may be preconditions for selling ecosystem services. Coffee growers in particular often interact with various outside organizations- either through coffee grower cooperatives or to receive government aid. Two Oaxacan respondents mentioned downstream users as potential buyers, which was a surprisingly infrequent response considering that downstream municipalities are the intended post-PSAH service buyers.

The majority of respondents did not think anyone besides the Mexican government would pay them for their services, or to conserve their forest. Half of the Oaxacan interviewees and all Yucatecan non-beneficiaries and beneficiary *avecindados* took this position. In the cases in which Oaxacan interviewees did see a potential for ES buyers, they typically listed government agencies or programs besides CONAFOR: PROCAMPO, PROFEPA, CONAGUA, SEMARNAT, CONAFOR, and PROARBOL. Yucatecan interviewees also

expressed a belief that conservation payments can only be expected to come from the government."

**Perceptions of CONAFOR Program Administrators**

During the interviews we conducted with state and national level PSAH administrators a number of common themes emerged concerning their perceptions of ways and means of improving the program's functioning and impact. First it is important to note that many of the recommendations given have either already been incorporated into more recent iterations of the PSAH or other CONAFOR PES programs including Fondos Concurrentes or are being considered for future iterations. That being said, throughout conversations with various stakeholders there were a few ideas mentioned frequently that are being pushed by either national or state level officials to enhance the program and do not show any opposition at this point. The most prominent topic was the quality of technical guidance for participants. State level officials consider the role of técnicos critical to the level of engagement of participants with the program and its overall objective since técnicos interact with participants more than they do. Therefore, there was an overall desire to increase the quality of information shared by técnicos with participants. One of the topics that state officials consider could be covered by técnicos is the existence of local PES mechanisms (i.e. Fondos Concurrentes).

During interviews with state level CONAFOR employees, a variety of recommendations and comments were given regarding the program's selection criteria, payment scheme and overall operation. Several officials brought to light the country's vast regional differences and the outcome of not considering these differences in both the targeting criteria and payment scheme. For instance, due to these differences the opportunity cost which the current payment scheme is based on is not an accurate representation of the opportunity cost in each region of the country, skewing the program's perception of what a sufficient incentive is for different applicants. Interviewees also considered that the lack of regional distinctions affects the type of participants enrolled and at times prevents potentially good participants from being accepted in the program. Therefore, employees advocated taking into consideration regional differences, namely opportunity cost and social capital, in the targeting criteria.

Following this sentiment, some employees suggested shifting towards a more decentralized program in which state level officials have greater responsibility and decision-making power over the design of the program. The level of suggested responsibility differs among respondents – from having a greater opinion on what criteria is chosen to being the body that decides what criteria is applied. The overall notion was to have greater involvement in the criteria choosing process in order to have regional differences shown. On a

broader scale, some employees also recommended having greater inter- and intra-agency collaborations in order to be more effective with their programs and the specific audiences they are targeting.

The most frequent suggestion was to include social factors such as selection and/or payment criteria. One interviewee stated that including the organizational capacity of a community – displayed through the level of internal rules – as a criterion could provide a sense of security for both the success of the program and the productive use of the payment. Another interviewee suggested including the organization level of an ejido – displayed through the level of internal rules and conflict, the frequency of Assembly meetings or the manner in which the *Comisariado* informs *ejidatarios* of expenses – as a payment criterion.

Another suggestion for both selection and payment criteria was to have state-level criteria aside from national criteria, once more, in an attempt to allow for local conditions to be considered and simultaneously give state officials greater say in program design. In terms of specific environmental targeting criteria suggestions, one interviewee suggested considering the potential of the forest to undergo forest management.

Payment scheme suggestions included:

- Differentiated payments for *tecnicos* based on the amount of assistance they provide to their participants in order to incentive them to engage with their program participants beyond the minimum required areas and expand onto environmental awareness and, if fitting, forest management.
- Payment rates based on more criteria, such as a poverty index or ethnicity.

While one of the strengths of CONAFOR's PES program has been the willingness and ability of administrators to adapt policy in response to feedback on the functionality of various elements, the rapidity with which the program has evolved has increased the difficulty to communicate these changes between the head and state offices and the state offices and beneficiaries. For instance, some state officials said they were not made aware of what propelled the payment scheme to change in 2010 nor how those sums were derived. Therefore, when beneficiaries question the nature of the change, state officials cannot say much beyond the information that participants already have.

Other pieces of information state officials mentioned they are not aware of include how the rules of operations are finalized, why payment schemes change, how payment schemes and amounts are formulated and how the model of deforestation risk originated.

In regards to targeting criteria particularly, there were a few points the majority of interviewees agreed on. There was unanimous support for the continued spread of biological corridors, particularly from those states that are

currently part of the Mesoamerican corridor, and the addition or current state of social criteria.

Along the same vein, most of the interviewees agree that the target audience of the program is and should continue to be ejidos, which is reflected in the targeting criteria. Support for favoring the selection of ejidos over small landowners is both environmentally and socially based. The majority see ejidos as a cost-effective way of using and spreading the resource to obtain higher environmental benefits. Others support favoring ejidos because of the socioeconomic improvement that comes with the resources provided to them. However, because of the regional differences in demographics and property ownership, state officials were on both sides of this debate. One state's main constituency was small landowners; therefore, their constituency is negatively affected by targeting criteria that favor ejidos.

Regarding payment schemes, most of the interviewees considered the current payment scheme the most effective one in terms of providing a fair payment to people with different land qualities. The current payment scheme uses differentiated payments based on the type of ecosystem and the risk of deforestation of the land parcel. However, two interviewees disagreed. One interviewee considered requiring a Program of Best Management Practices (*Programa de Mejores Practicas de Manejo*), which was required from 2006-2009, to be the best option because the interviewee considered it required participants to take on more activities than the current scheme. The other deviating interviewee mentioned that having differentiated payments has created social conflicts. When one participant is considered Area 3 while their also-participating neighbor is considered Area 2 and they are not aware of the reason for the different payments, complaints or requests for clarifications have surfaced. Most of the times this situation has developed, participants have understood the reasoning behind the differentiated payments; however, the situation could also be avoided altogether by making clear the program's rules.

In terms of the specific payment scheme criteria considered, those interviewees that were aware of the deforestation risk model's origin were not satisfied with the output of the model, variables used and lack of information on the methodology used. Additionally, the majority of state interviewees considered the model to be outdated and in need of refining. At the same time, some interviewees recognized that CONAFOR does not have an alternative model available currently.

**SUMMARY**

In general, we found that beneficiaries of the program were aware of the program and were positive about the perceived impacts of the program, although knowledge of the program is highest among community leaders and private

property landholders. Most beneficiaries perceive the main benefit of the program to be extra income, and many of them also mention the importance of support for forest conservation. A high proportion of both ejidos and private property beneficiaries (between 30 and 50%) reported that they would like to continue being enrolled in the program, and relatively smaller numbers of participants (15-30%) intend to use the currently enrolled land for other productive activities after the program is over. Beneficiaries and non-beneficiaries alike are skeptical of the potential to directly sell ecosystem services to private parties when the program ends. Interviews with CONAFOR state-level program administrators revealed a number of suggestions for means of improving program impacts, the majority of which are already being incorporated into the program rules.

# PART III. ASSESSING ENVIRONMENTAL IMPACTS

This section of the report details the progress to date on the assessment of avoided deforestation impacts of the program. The first section is based on coarse-resolution satellite data from MODIS as well as national program data on accepted and rejected applicants. The second section provides an update on our efforts to produce more accurate measures of forest disturbance using Landsat satellite data.

## Section 1: Impact analysis of avoided deforestation

This section details the impact analysis on deforestation conducted to date. This work is quite preliminary. We anticipate conducting a related analysis, including measurement of potential spillover effects, once the more detailed remote sensing data is available for the footprints currently under analysis by the remote sensing group.

**Data**

Using program data and GIS boundaries of program applicants from CONAFOR, we construct a spatial database of all applicants to the program from 2004-2009.[20] To analyze program effects from 2004-2009, we use points as a unit of analysis; intersecting these points with the program polygons allows us to clearly code the program status of each point in each year.[21] The points are a random sample from within PSAH applicant boundaries from 2004-2009 which were classified as one of six forested categories in the INEGI Series III land use layer (circa 2002). To minimize spatial autocorrelation, we sample only at a density of 1 point per square km (~38,000 points) and cluster all standard errors by property. In order to understand deforestation behavior in lands outside of program applicants during the same time period, we also randomly select 50,000 points which were classified as forested prior to the start of the program from across all of Mexico.[22]

For this initial assessment of the environmental effectiveness of the program, we use the average dry season normalized difference vegetation index

[20] We analyze the 2004-2009 cohorts but we do collect and overlay the boundaries of the 2003 and 2010 PSAH recipients in order to correctly control for recipient status in all years.

[21] This is necessary because of the complex spatial overlap of applications between years. For instance, a landowner may choose to apply with a portion of his land in one year and then if he is rejected, apply again with a different portion in the next year.

[22] We eliminate points which had 2003 NDVI values indicating they were not in forest in 2003. Specifically, we drop points where the 2003 NDVI is less than 0.3 in regions 1, 2, and 3 and less than 0.6 in region 4).

(NDVI) in each year from 2003-2011 as a measure of forest cover[23], as described above. Although the data used here was newly constructed by us, similar methodology has been previously established and field-tested by the Mexican National Forestry Commission (CONAFOR 2011, Meneses-Tovar 2009a,b). Economists have relied on NDVI decreases to measure deforestation in previous research in both developed and developing countries (Mansfield et al. 2005, Burgess et al. 2011, Foster and Rosenzweig 2003).

The key advantages of the MODIS data are its temporal density (weekly products) and wall-to-wall coverage of Mexico. Frequent passes by the satellites mean that data is complete even for areas which experience significant cloud cover (such as the Yucatan peninsula) so that it is feasible to construct a wall-to-wall dataset for all of Mexico for each year. The downside is that MODIS is spatially coarse, with resolution at 250m pixels (~ 6 ha). This does not mean we cannot detect smaller areas of forest loss – NDVI is a continuous measure, so clearing or degradation of smaller areas will still decrease the NDVI value. However, we are limited in that we do not know exactly where in each 250 x 250 m area this loss or degradation occurred. Given the average size of the properties enrolled between 2004-2009 is 680 ha (> 100 pixels), we believe the resolution of the data is appropriate for this analysis. However, since small areas of clearing do happen in Mexico, particularly in the south, we maintain the continuous measures of NDVI in our analysis rather than classifying each pixel as forested or non-forested. We do also check robustness of the results to several alternate definitions of forest cover.[24] Finally, we note that all measures of forest cover are sensitive to seasonal vegetative cycles ("phenology") and annual variation in rainfall. More rainfall at the right time will increase the density of leaf cover, particularly in deciduous forests. To control for this variability, our regression models include measures of annual dry season (Feb-April) and growing season rainfall (May-Jan) as well as controls for extreme rainfall events described below.[25]

## Selection of controls and regression models

[23] NDVI is a measure of the "greenness" of vegetation based on the reflectance signatures created by leafy vegetation versus other land cover (NASA 2012).

[24] Alternate measures of forest health included the log of NDVI and NDVI normalized to have a mean of zero and standard deviation of one in each year and region. We also classify pixels into forest and non-forest categories based on expected NDVI values of forest and non-forest categories. Results available from authors.

[25] Rainfall data are from NOAA NCEP CPC Mexico daily gridded realtime precipitation (.25 x .25degrees).

As described in the introduction, in order to understand how PSAH participation affects forest cover (measured by the greenness of vegetation) we constructed a reasonable counterfactual case by comparing accepted and rejected applicants across time. A key advantage of using controls drawn from the applicant pool is that all owners have demonstrated their (otherwise unobservable) desire to enroll in the program, revealing that their expected participation costs are sufficiently low to motivate application, and perhaps that they share a "conservation oriented" inclination.[26] However, even with program applicants as controls, there still may be other remaining characteristics which could be correlated with selection into the program and changes over time in deforestation. To address this problem, we investigated the selection process, pre-match data on the basis of relevant characteristics, and estimate panel regressions including appropriate controls. Our preferred specification includes property-level fixed effects, in order to control for any unobservable fixed characteristics of the parcels.

Selection into the PSAH program is described in more detail in Part I of this report. Broadly, the requirements are that the submitted parcels have a set amount of forest cover to start (> 80% in 2003-2005; > 50 in 2006-2009) and be inside designated eligible zones.[27] From 2006 onwards, priority was also given to properties with a high risk of deforestation (as measured by INE's v1 layer), in high poverty municipalities, and with other specific environmental or social criteria such as location within protected areas or number of female heads of households (Shapiro and Castillo 2012). We solicited data on the reasons for rejection in each year and find that there are four main reasons for rejection in our panel dataset: 1) having all the qualifications but being rejected for lack of funding due to program budget constraints, 2) failing to meet the minimum forest cover requirement, 3) being located outside of the eligible zones, 4) having incomplete paperwork or failing to meet other technical requirements. More than 40% of our control points are in the first group, which is the best comparison group because these applicants met all of the requirements but the money ran out before arriving at the level at which applicants were located on the ranked list of applicants within their state. Approximately 30% of the applicants in our sample were rejected for the second two reasons, which constitute selection on observables. To account for this selection, we match on or control for appropriate

[26]The main criticism of previous research on PES programs is that results may be driven by possible selection bias due to unobservable characteristics driving lower opportunity costs of enrolled parcels compared to non-applicant controls.

[27] The characteristics determining eligibility or priority include: being in a watershed which supplies a locality with population greater than 5000, being within a watershed that is characterized as overexploited, being in a priority mountain or protected area and being within a poor or majority indigenous municipality.

geographic characteristics as described below. The fourth reason for rejection is potentially more problematic: missing paperwork could reflect lower institutional capacity that is not directly observable and might be correlated with deforestation (approximately 20% of our sample). To minimize this problem, we limit our analysis to applicants that have sent in geo-referenced property boundaries and have already passed through a first round of screening, ensuring a reasonable level of institutional capacity. We also match on municipal poverty levels and tenure type, which may correlate with institutional capacity.

Prior to estimation, we match points within accepted parcels to rejected parcels on the basis of characteristics which determined selection into the PSAH program and could drive deforestation patterns. We use 1:1 covariate matching with replacement on the Mahalanobis metric. This means that we select properties which are most similar to each other in terms of observable characteristics, where a higher weight is given to characteristics in which there is a greater variance. The covariates we match on are slope, elevation, distance to the nearest locality with population greater than 5000, baseline forest type, baseline municipal poverty, overlapping with an overexploited aquifer, the degree of water scarcity, being inside one of the priority mountains, and being in a municipality with majority indigenous population. Matching is conducted within region and tenure type (common vs. other) to ensure exact matches on these characteristics. These controls were chosen on the basis of the reasons for rejection and the economic drivers of deforestation in Mexico (Alix-Garcia 2007, Alix-Garcia et al. 2005, Muñoz-Piña et al. 2008, Bray and Klepeis 2005, Deininger and Minten 1999).

Our preferred specification uses as an outcome variable the mean dry season NDVI value for a particular point. The beneficiary variable is equal to 1 if the point was enrolled in the program in the previous year and 0 if not. Control variables include the natural log of annual dry season rainfall, of annual growing season rainfall, the standard deviation of rainfall across the year, and a dummy variable for being in the top 10th percentile of rainfall during the hurricane season (October/November). The specification also includes state/year fixed effects, which control for all exogenous shocks associated with a particular state and year, and indicators for different vegetation types to control for unique NDVI signatures of these different categories. Finally, we include property level fixed effects to control for possible unobservable fixed characteristics. These effects are equivalent to including a variable for each applicant that controls for all of the specific characteristics of that applicant that do not change over time, such as distance to city, soil type, and institutional features that change slowly, like average education level. Standard errors are clustered at the property level to account for spatial and serial correlation.

**Summary statistics**

Table 38 shows summary statistics for the unmatched and matched treated and comparison groups and the normalized difference in means (Imbens and Wooldridge 2009). For comparison, we also include summary statistics and normalized differences for a random sample of initially forested points outside of program applicants. From Table 38, we see that beneficiary lands are somewhat closer to major localities (with population > 5000) than the non-beneficiaries (.167 standard deviations) and all other forest points (.147 standard deviations) but have higher slope and elevation than the non-beneficiaries and the random sample of forest points. The mean risk of deforestation among beneficiaries, according to Mexico's Instituto Nacional Ecología (INE),[28] is slightly higher among the accepted applicants vs. rejected applicants (.029 standard deviations) and somewhat lower (-.204 standard deviations) than all randomly selected forest points. Compared to all forest in the country, the beneficiaries over-represent bosque mesofilo (cloud forest) and bosque coniferas (coniferous forest), and under represent selva baja (low-lying deciduous rainforest). This distribution of forest types reflects CONAFOR's stated focus on bosque mesofilo, which has been - more strongly linked to hydrological services (Martínez et al. 2009, Bruijnzeel, 2004). In addition, the beneficiaries have a substantially higher probability of being in an overexploited aquifer than all forest points, (.161 vs. .122), as well as a lower degree of water availability (6.82 vs. 7.18), and a higher likelihood of being in a priority mountain area (.262 vs. .068). These differences also reflect CONAFOR's efforts to target the program to areas where hydrological services are most important. With respect to the social goals of the program, we see that the beneficiaries are in municipalities with slightly higher poverty index values (.267 vs .265 and .239) but these differences are quite small (0.001 and 0.019) when normalized by standard deviations. However, the program clearly enrolled more land in municipios with majority indigenous populations (.380 vs. .253 and .248) and more land in common properties (88.0 % vs. 79.8 % and 60.4 %) and these differences are also substantial in standard deviation terms.

Taken together, these statistics suggest CONAFOR was moderately successful in targeting the program to areas with a substantial risk of deforestation, potential for hydrological services benefits, and more poverty. A major concern about PES programs has been that it will enroll only those areas with a very low risk of deforestation. These statistics indicate that this is not the case for Mexico's program. Within the available applicants, CONAFOR appears to have selected those which are closer to urban areas, have a higher risk of

[28] INE's 5 point scale."Index of Economic Pressure to Deforest / Risk of Deforestation" version 1. Methodology at http://www.ine.gob.mx/irdef-eng.

deforestation on INE's layer, more water scarcity, and have higher poverty. However, the beneficiaries do have higher slope and elevation and a somewhat lower risk of deforestation when compared to all other forested points-- this may indicate that the payments are currently too low to attract applicants with the highest risk of deforestation. Table 38 shows the same summary statistics for the sample of matched beneficiary and non-beneficiary applicant points. Matching substantially improves the balance across distance to urban areas, baseline poverty and forest type, although we note that the matched non-beneficiaries have somewhat higher slope and elevation and lower likelihood of being in a majority indigenous municipio. Post-matching, none of the normalized differences are greater than .25 standard deviations, which is the rule of thumb suggested by Imbens and Wooldridge (2009).

## Table 38: Summary statistics: points within applicant boundaries and other forested points

### a. Unmatched

| Variable | Beneficiaries | | Non-beneficiaries | | Norm diff | Other forest points | | Norm diff |
|---|---|---|---|---|---|---|---|---|
| | mean | Sd | mean | sd | | mean | sd | |
| Slope (deg) | 12.35 | 9.94 | 11.32 | 9.64 | 0.075 | 10.27 | 9.522 | 0.151 |
| Elevation (m) | 1537 | 980.8 | 1436 | 921.0 | 0.075 | 1161 | 886.7 | 0.285 |
| Dist to loc > 5000 (km) | 32.94 | 22.06 | 38.76 | 26.00 | -0.167 | 38.11 | 27.36 | -0.147 |
| Muni poverty index | 0.267 | 1.121 | 0.265 | 1.127 | 0.001 | 0.239 | 1.019 | 0.019 |
| Common property | 0.880 | 0.325 | 0.798 | 0.401 | 0.159 | 0.604 | 0.489 | 0.470 |
| Overexploited aquifer | 0.161 | 0.367 | 0.122 | 0.328 | 0.078 | 0.0742 | 0.262 | 0.192 |
| Water availability | 6.823 | 1.698 | 6.859 | 1.526 | -0.016 | 7.180 | 1.311 | -0.167 |
| Priority mountain | 0.262 | 0.440 | 0.116 | 0.321 | 0.268 | 0.0680 | 0.252 | 0.383 |
| Majority indigenous | 0.380 | 0.485 | 0.253 | 0.435 | 0.195 | 0.248 | 0.432 | 0.203 |
| Manglar | 0.0067 | 0.081 | 0.0203 | 0.141 | -0.084 | 0.0090 | 0.0946 | -0.019 |
| Bosque encino | 0.213 | 0.409 | 0.267 | 0.443 | -0.091 | 0.225 | 0.418 | -0.021 |
| Bosque mesófilo | 0.0900 | 0.286 | 0.0422 | 0.201 | 0.137 | 0.0314 | 0.1745 | 0.175 |
| Selva alta | 0.143 | 0.350 | 0.150 | 0.357 | -0.014 | 0.154 | 0.361 | -0.023 |
| Selva baja | 0.144 | 0.351 | 0.180 | 0.384 | -0.070 | 0.311 | 0.463 | -0.289 |
| Bosque coniferas | 0.405 | 0.491 | 0.341 | 0.474 | 0.094 | 0.269 | 0.443 | 0.205 |
| Risk of defor | 2.455 | 1.331 | 2.401 | 1.301 | 0.029 | 2.847 | 1.390 | -0.204 |
| Mean ndvi | 0.625 | 0.153 | 0.573 | 0.162 | 0.234 | 0.556 | 0.162 | 0.310 |
| N | 17881 | | 18456 | | | 44104 | | |

**b. Matched**

| Variable | Beneficiaries | | Non-beneficiaries | | Normalized difference |
|---|---|---|---|---|---|
| | Mean | Sd | mean | Sd | |
| Slope (deg) | 12.14 | 9.84 | 13.03 | 9.45 | -0.066 |
| Elevation (m) | 1538 | 988.2 | 1637 | 905.5 | -0.074 |
| Dist to loc > 5000 (km) | 32.99 | 21.97 | 32.97 | 21.92 | 0.001 |
| Muni poverty index | 0.259 | 1.11 | 0.223 | 1.09 | 0.023 |
| Common property | 0.884 | 0.320 | 0.860 | 0.347 | 0.052 |
| Overexploited aquifer | 0.160 | 0.367 | 0.172 | 0.378 | -0.023 |
| Water availability | 6.805 | 1.69 | 6.714 | 1.62 | 0.039 |
| Priority mountain | 0.244 | 0.430 | 0.204 | 0.403 | 0.068 |
| Majority indigenous | 0.377 | 0.485 | 0.301 | 0.459 | 0.114 |
| Manglar | 0.0064 | 0.080 | 0.0061 | 0.078 | 0.003 |
| Bosque encino | 0.213 | 0.409 | 0.261 | 0.439 | -0.080 |
| Bosque mesófilo | 0.0834 | 0.277 | 0.0696 | 0.255 | 0.037 |
| Selva alta | 0.141 | 0.348 | 0.1090 | 0.312 | 0.069 |
| Selva baja | 0.146 | 0.353 | 0.1259 | 0.332 | 0.041 |
| Bosque coniferas | 0.411 | 0.492 | 0.4285 | 0.495 | -0.026 |
| Risk of defor | 2.47 | 1.33 | 2.41 | 1.28 | 0.033 |
| N | 17137 | | 5228 | | |

Matches are found using 1:1 covariate matching with replacement and calipers of 2 on the Mahalanobis metric. Matching is conducted within region and tenure type on the basis of slope, elevation, poverty index, distance to nearest locality with population greater than 5000, forest type, overlapping with an overexploited aquifer, the degree of water scarcity, being inside one of the priority mountains, and being in a municipio with majority indigenous population. Normalized difference is the difference in average covariate values, normalized by the standard deviation (Imbens and Wooldridge 2009). Risk of deforestation is available for 16883,16691 and 37394 unmatched observations and 16142 and 4732 matched observations.

## Average impacts

Table 39 gives our main estimates of program impacts on mean NDVI, using the estimating equation described above with property-level fixed effects. Column 1 shows average program impact while columns 2-5 test for heterogeneity in impacts. The coefficient in column 1 indicates that the average impact of receiving the program is an increase of 0.0041 in mean annual NDVI. On matched non-beneficiary properties, the average annual loss of NDVI, controlling for rainfall, vegetation type, and state, is -.0013 for one year. Over five years, this results in a loss of -.0065. Our estimates imply that the program reduces this loss to -.0025, which constitutes an "avoided NDVI loss" metric of nearly 62% (.004/.0065). It is difficult to establish the correlation between these numbers and land use change. One possible interpretation of the numbers is that the program reduces either degradation and/or deforestation.

Table 39: Impacts of PSAH 2004-2009 on forest cover: property fixed effects

| | Dependent variable: mean NDVI | | | | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Beneficiary | 0.0041*** | 0.0038*** | 0.0069*** | 0.0078*** | 0.0047*** | -0.0014 |
| | (0.0008) | (0.0010) | (0.0012) | (0.0021) | (0.0008) | (0.0016) |
| Benef x center | | 0.0031* | | | | |
| | | (0.0017) | | | | |
| Benef x southwest | | -0.0016 | | | | |
| | | (0.0018) | | | | |
| Benef x southeast | | -0.0008 | | | | |
| | | (0.0036) | | | | |
| Benef x km to large locality | | | -0.0001*** | | | |
| | | | (0.000033) | | | |
| Benef x log(slope) | | | | -.0017*** | | |
| | | | | (0.0008) | | |
| Benef x municipal poverty index | | | | | -0.0030*** | |
| | | | | | (0.0005) | |
| Benef x common property | | | | | | 0.0063*** |
| | | | | | | (0.0018) |
| N properties | 3644 | 3644 | 3644 | 3644 | 3644 | 3644 |
| N total | 201285 | 201285 | 201285 | 201285 | 201285 | 201285 |
| Rsq | .253 | .253 | .253 | .261 | .254 | .253 |

* p< .10 ** p < .05 *** p < .01

Property-level fixed effects model (equation 1). Robust standard errors clustered at the property level in parentheses. Dependent variable is mean ndvi (ranges from 0 to 1). Regressions use data from program beneficiaries and matched rejected applicants; matching as described in footnote above.

One pattern which is evident looking at our GIS data is that deforestation is highly dispersed spatially. Rather than a frontier situation, where we might expect lots of clearing in a few areas, deforestation in Mexico is generally

scattered in small amounts over vast land areas and most individual landowners are clearing only small amounts in percentage terms. Data from CONAFOR's Monitoreo Forestal indicates that between 2003 and 2008, the average percent area of suspected deforestation per municipality was 0.51 % (with the 25th percentile at 0.14% and the 75th percentile at 1.6%). While these small amounts clearly add up to large areas deforested in total, given the large land area of Mexico, the pattern means that it is very difficult for policymakers to target payments only to the "marginal hectares" that would be cleared in the absence of the program. Whether or not there are opportunities for managers to increase the cost-effectiveness of the program depends on whether there is systematic heterogeneity in avoided deforestation impacts that can be better exploited.

**Heterogeneity in environmental impacts across space**

Motivated by the simple economic framework discussed in section 1, we test for heterogeneity in effectiveness across region, distance to the nearest urban locality, slope, baseline municipal poverty and tenure type. We find (Table 39, column 2) that effects across the four regions are not significantly different from each other, although the coefficients indicate possibly higher avoided NDVI loss in the central region (.0038+.0031 = .0069).[29] We do see significant heterogeneity by distance to urban area and slope, both key determinants of land quality. As expected, we see less avoided NDVI loss as we move away from cities and as slope increases. For instance, the magnitudes suggest that at 10 km from the nearest large locality (10th percentile of distance), the marginal effect of the program was three times greater than at at 65 km (90th percentile). The coefficient on the interaction between beneficiary and slope also indicates a much greater marginal effect at the 10$^{th}$ percentile of slope than at the 90$^{th}$.

In terms of social goals, we find less avoided NDVI loss at higher levels of baseline municipal poverty, unfortunately suggesting that there is no easy win-win strategy to increase avoided deforestation and make the program more progressive. The estimates indicate that at a municipal poverty index designated by CONAPO as "low" (-1.3 to -.7), avoided NDVI loss was nearly twice what it was at a municipal poverty index of "high" (-.1 to 1). However, when we break recipients down into common property beneficiaries (ejidos and comunidades) versus private and other types of beneficiaries, we find that the program is most effective in the common properties, with significant impacts occurring only in

[29] The different between region 1 and region 2 is significant at the 5% level in some specifications but we do not believe it is a substantial difference, particularly if we take into account the fact that the differences in average NDVI between forested and non-forested points vary somewhat by region anyway; in the north the difference is approximately 0.3 rather than 0.2.

ejidos and comunidades, where the coefficient of .006 completely eliminates the downward NDVI trend in the non-beneficiary data, thus indicating 100% avoided NDVI loss. Impacts in private properties are not significantly different from zero. This suggests possible win-win targeting if more payments were given to common property beneficiaries, who are in general more poor than private property landowners.

**Heterogeneity in impacts across time.**

In a final step of the NDVI analysis, we examine differences in environmental effectiveness across different cohorts. The results are shown in Table 40, and include two robustness checks: limiting the sample to the 90% best matches (column (2)) and limiting the control group to points falling within eligible zones (column (3)). We see positive program impacts in almost every cohort, all of which are significant, with the exception of 2005 and 2006. The magnitudes of the effects across cohorts for which they are significant are quite similar in value.

Combining this with the information on targeting rules and the characteristics of enrollees, we observe that most years of the program have similar estimated effectiveness, except for 2005, which is not statistically significant, and 2006. The year 2006 corresponds to a time of significant change in the program, in particular, the expansion of eligible zones and a re-prioritization of the program. Referring back to the summary statistics in

Table 38, we note that during these two years, the rejected properties had a higher risk of deforestation than the enrolled properties. Since these properties are the counterfactual in our analysis, it is not surprising that we do not find significant results in these two years.

The 2007-2009 cohorts correspond to a return to effectiveness, possibly indicating a lagged learning effect in the implementation of the policy. It is important that we continue to see significant impacts of the policy even after increased social targeting was put in place. However it is fair to note that we do not see dramatic improvements in overall avoided NDVI loss impacts after risk of deforestation was introduced as a criterion, possibly suggesting that social goals limited the ability to target only based on avoided deforestation. Unfortunately, the coarse nature of the satellite data limits our ability to analyze differential impacts across cohorts at this time. It is possible that while these additional rules did not change overall gross avoided NDVI loss impacts of the program, they did change the small-scale spatial patterns of deforestation or the quality of the forest enrolled – outcomes that we are not well-placed to measure.

**Table 40: Cohort by cohort analysis**

| | Dependent variable: mean NDVI | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| Beneficiary 2004 | 0.004*** | 0.006*** | 0.006*** |
| | (0.002) | (0.002) | (0.002) |
| Beneficiary 2005 | 0.003 | 0.002 | 0.003 |
| | (0.003) | (0.002) | (0.002) |
| Beneficiary 2006 | 0.001 | -0.001 | 0.001 |
| | (0.002) | (0.002) | (0.002) |
| Beneficiary 2007 | 0.005*** | 0.004*** | 0.006*** |
| | (0.001) | (0.001) | (0.001) |
| Beneficiary 2008 | 0.004** | 0.004** | 0.004*** |
| | (0.002) | (0.002) | (0.002) |
| Beneficiary 2009 | 0.004** | 0.003** | 0.004*** |
| | (0.002) | (0.002) | (0.002) |
| N total | 196929 | 135189 | 189063 |
| Rsq | .223 | .241 | .228 |

* p< .10 ** p < .05 *** p < .01

Property-level fixed effects model (equation 1). Robust standard errors clustered at the property level in parentheses. Dependent variable is mean ndvi (ranges from 0 to 1). Regressions use data from program beneficiaries and matched rejected applicants; matching as described in footnote to Table 1. Column 1 uses the full sample. Column 2 restricts the sample to the 90% best matched points, and column 3 uses only points within eligible zones.

## SUMMARY

We find that the PSAH program has significantly reduced NDVI loss compared to what would have been expected in the absence of the program. We also find

significant heterogeneity in avoided deforestation impacts, with larger impacts in communally held lands, on higher quality land, and in less poor municipalities. Together, these results indicate a moderate avoided deforestation impact, with room for stronger impacts through improvements in targeting of payments.

Considering the impact results from this section as well as Part II above, our analysis indicates only limited potential for changes in targeting that could produce both more avoided NDVI loss and more poverty alleviation. More avoided NDVI loss could be gained by additional targeting to high quality lands (for instance near urban areas and with lower slope) but these changes would likely make the program less progressive. More avoided NDVI loss might also be achieved by raising payments in order to induce enrollment of land at a higher risk of deforestation. This could increase positive wealth impacts but would mean higher payments to fewer individuals unless the program budget is also expanded. Our results indicate that one possibility for a "win-win" on both dimensions is additional targeting of payments to communally-owned properties, which are poorer on average and also show higher avoided NDVI loss impacts.

## Section 2: Methods to assess deforestation

This section describes the progress to date on accurately measuring the impact of the PSAH program on land use change, the main outcome of interest for the purpose of assessing the environmental effectiveness of the program. The remote sensing component of this assessment examined more than 400,000 square kilometers of land over a twenty-year period. The analysis' large spatial and temporal scales necessitated the use of a host of satellite imagery datasets and analytical tools. The ultimate goal of the analysis is to generate binary forest/non-forest maps for each year in the study area, and use these maps to determine the locations and dates of deforestation.

At the coarsest spatial scale, we used phenology data from the Moderate Resolution Imaging Spectrometer (MODIS) to evaluate the onset and conclusion of the annual vegetation growth season in the study area. Using these known annual vegetation growth timeframes, we selected higher resolution Landsat imagery to determine the locations and timing of deforestation within the study area. To minimize the effects of inconsistent atmospheric conditions, sun angle, and Landsat view angle between Landsat images, we used the National Aeronautical and Space Administration's (NASA's) Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) atmospheric correction algorithm to normalize all Landsat imagery to values of surface reflectance. Due to persistent cloud cover over the study area during the growing season, we used the Function of Mask (Fmask) cloud detection algorithm to locate and screen clouds and cloud shadows. We also developed an image compositing algorithm that selected the best cloud-free pixels from each Landsat scene for each year to create annual cloud-free composite images. Unfortunately, the persistent clouds and limited availability of Landsat imagery in the southernmost footprints resulted in many composites lacking complete cloud-free coverage. In Landsat footprints where a perennial lack of cloud-free data prevents the generation of cloud-free composite images, we are considering creating and evaluating cloud-free composite images for every two years (e.g., 2000/2001, 2002/2003, etc.)

Once we created the cloud-free composite images, we were able to monitor each pixel in the study area through time to detect spectral changes indicative of deforestation and forest regrowth. We classified each composite Landsat image into a binary forest/non-forest map using a support vector machine algorithm (SVM) and five-hundred sample points within each image. These annual forest-non-forest maps allowed us to track the status of all forest pixels through time, indicating the location and year of deforestation and afforestation. Though we initially used the Vegetation Change Tracker (VCT) algorithm to automatically generate cloud-free composite images, sample forest-non/forest points, and classify forest-non-forest images, we ultimately found this algorithm's accuracy unreliable due to its tendency to incorrectly identify missing data values

resulting from the scan line corrector failure on Landsat 7's ETM + sensor as deforestation. As a result, we relied exclusively on manual sample point generation and image classification methods. At present, we have completed classificationsfor two footprints, with annual accuracies of approximately 70% to 75% . However, upon completing the classifications of the annual composite images, we will conduct trajectory analyses on each 20-year stack of classified images to determine the locations and dates of deforestation in the study area.

**MODIS analysis**

As the spectral responses of Mexico's forests vary according to seasonal rainfall patterns, our analysis included only the Landsat images corresponding to the wet summer months for each footprint. Had we included images from drier months in our analysis, we might have erroneously identified a seasonally leafless deciduous forest as an area of deforestation. Because the onset of the summer rainfall does not have a consistent date for each Landsat footprint, we analyzed vegetation index data from the Moderate Resolution Imaging Spectrometer (MODIS) to determine the effective growing season start and end dates, between which Landsat images were selected for the analysis. We selected the MODIS data because of the sensor's large spatial coverage (roughly 1,000,000 square kilometers per image), frequent repeat cycle (approximately two days), and our previous experience using these data for a similar study in Russia.

**Growing season analysis**

A crucial part of selecting the images to be used from the Landsat archives is to have images from the same seasonal growing stage. We selected images from the growing season based on the two MODIS Vegetation Indices datasets (MODIS Terra and Aqua VI) 16-Day L3 Global Collection 5.0 (MOD13Q1 and MYD13Q1) from January 1, 2003 to December 31, 2010 (231.65 m resolution, or 5.36 ha) in the whole country. Data was retrieved from the Land Processes Distributed Active Archive Center (LP DAAC, http://lpdaac.usgs.gov). The combined MODIS VI dataset includes weekly reflectance, NDVI, and quality data. We analyzed 250-m 16-day red reflectance data, 250-m 16-day near-infrared reflectance data, and 250-m 16-day normalized difference vegetation index (NDVI) data, each of which is available for 46 dates per year, from both Terra and Aqua datasets.To identify whether or not phenology metrics can be used to map forest and non-forest areas we calculated eleven phenology metrics for each year. Phenology metrics are descriptive data of the growing period, calculated from fitted functions for each year of the NDVI time-series. The use of a fitting function smooths anomalies in the data, thereby reducing noise and ensuring data consistency. We used the program TIMESAT to smooth the raw NDVI time series data and to calculate eleven phenology metrics for each year of the time

series (Jonsson & Eklundh, 2004). These metrics are as follows:

1. Start of the growing period: week of the year at which the left edge of the fitting function increased to 20% of the full amplitude of the growing period (i.e., the difference between the minimum NDVI, starting from the beginning of the year and the largest NDVI value of the fitting function);

2. End of the growing period: week of the year at which the right edge of the fitting function decreased to 20% of the amplitude of the growing period;

3. Length of the growing period: time in weeks between the start and the end of the growing period;

4. Base level: mean of minimum NDVI values before the start and after the end of the growing period;

5. Middle of the growing period: the mean (week) of the two weeks per year at which the left edge of the fitted function has increased to the 80% level, and the right edge has decreased to the 80% level;

6. Maximum NDVI value for the fitted function during the growing period;

7. Amplitude of the growing period: difference between the base level NDVI value and the largest NDVI values of the fitted function (in NDVI values);

8. Rate of increase at the beginning of the growing period: ratio of the difference between the left 20% and 80% levels and the corresponding time difference in weeks (in NDVI values / Time (weeks));

9. Rate of decrease at the end of the growing period: absolute value of the ratio of the difference between the right 20% and 80% levels and the corresponding time difference in weeks (in NDVI values / Time (weeks));

10. Large growing period integral: the area under the curve of the fitting function from the start to the end of the growing period;

11. Small growing period integral: the area under the curve of the fitting function between the start and end of the growing period starting from the base level of the growing period.

The NDVI values in the fitted function ranged from – 3,000 to 10,000 with a scale factor of 0.00001.

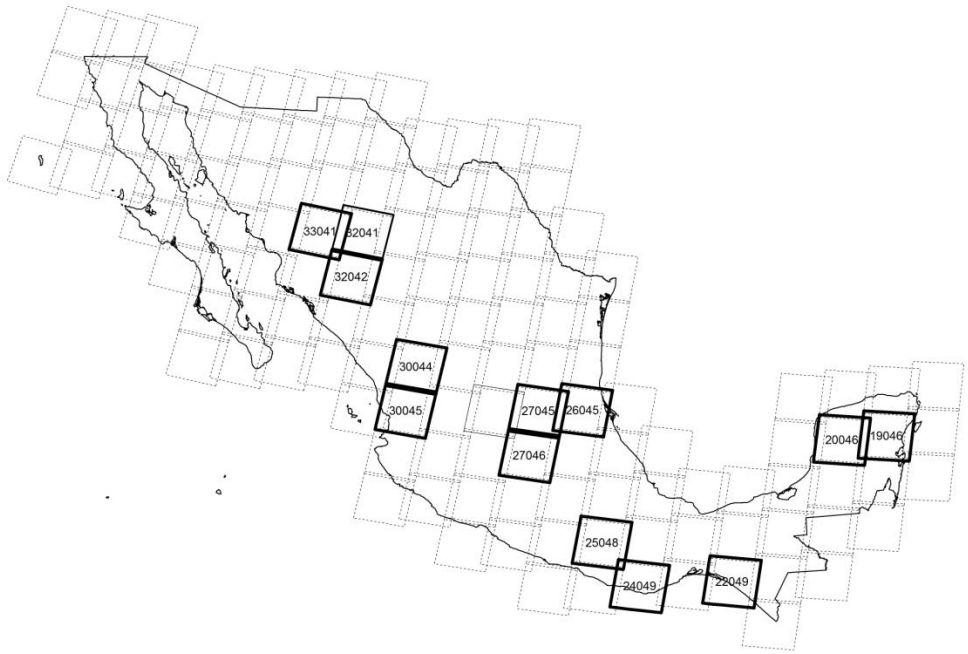
The results of this analysis indicate the date in which the events described above occurred at pixel level. We then summarized this phenology information by averaging it over the entire footprint. The resulting tables allowed us to choose the

dates of similar phenological stages to avoid the possibility of erroneous change detection simply due to examining vegetation from different phenological phases. We also used this analysis to provide the input for the estimation of the vegetation changes in the impact analysis described in Section 3. At present, we do not have complete phenology information for the entire study area, and as such are provisionally analyzing Landsat images from June 1 to September 30 of each year. Once we have completed the MODIS-based phenology analysis, we will tailor the input imagery dates for each year and Landsat footprint to accurately capture the growing season for each year in each Landsat footprint. Additionally, the MODIS phenology data provided the outcome measure used in the impact analysis described later in this report.

**Landsat Analysis**

Because even the finest spatial resolution of MODIS' spectral bands is 250 meters—much too coarse to accurately gauge small-scale deforestation in Mexico, we relied upon 30 meter resolution Landsat data for the actual deforestation analysis. Landsat data have a long history of being used in similar land change analyses, and the fact that the United States Geological Survey freely distributes the entire Landsat archive made these data very attractive to our data-intensive analysis. We measured annual deforestation rates during the period 1990-2010 using Landsat TM and ETM+ imagery in 13 regions across Mexico. Each of these regions corresponds to the area covered by a single Landsat footprint (Figure 10). The identifying codes for these footprints are 033041, 032041, 032042, 030044, 030045, 027045, 026045, 027046, 025048, 024049, 022049, 020046 and 019046. Landsat data for each growing season of the study years as determined by the aforementioned MODIS phenology analysis were downloaded from the United States Geological Survey's (USGS's) GLOVIS web portal (glovis.usgs.gov). These data were downloaded as seven individual bands of geo-referenced imagery in TIFF format and were subsequently processed according to the steps outlined below

**Figure 10: Landsat footprints covering Mexico. Dark selection corresponds to the areas of analysis.**




## Preprocessing

*Atmospheric Correction*

In order to minimize the effects of variable atmospheric conditions in the Landsat imagery, we preprocessed all imagery with the National Aeronautical and Space Agency's (NASA) Landsat Ecosystem Disturbance Adaptive Processing System (LEDAPS) software (http://ledaps.nascom.nasa.gov/tools/secure/PREPROCESS). LEDAPS converts the digital numbers of a Landsat TIFF input scene into an atmospherically corrected HDF-format output image composed of surface reflectance values which can be compared through time and space to surface reflectance values from other Landsat images (Wolfe *et al*., 2004). LEDAPS uses the relationship between the mid-infrared (2.2 micrometer wavelength) and visible (0.45 – 0.65 micrometer wavelength) image bands over dark vegetation to determine the aerosol optical thickness in the image (Wolfe *et al*., 2004). LEDAPS corrects for water vapor and barometric pressure variances using the National Oceanic and Atmospheric Administration's (NOAA) National Centers for Environmental Prediction (NCEP) reanalysis data and ozone variances with NASA's Total Ozone Mapping Spectrometer (TOMS) data (Wolfe *et al*., 2004). In addition to creating a surface reflectance output image for each Landsat input

image, LEDAPS also creates a top-of-atmosphere reflectance image and a cloud and snow mask based upon the Automatic Cloud Cover Assessment (ACCA) algorithm (Irish *et al*., 2006).

**No Atmospheric Correction** **LEDAPS**
**Atmospheric Correction**

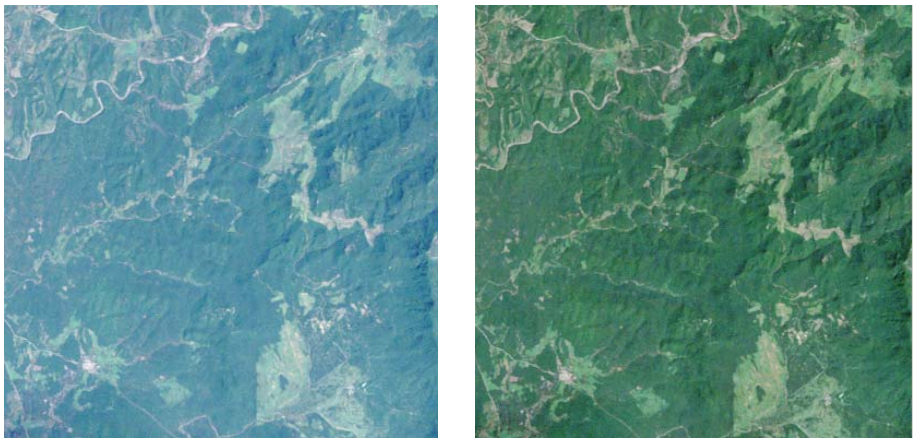


Figure 2: Uncorrected digital number imagery (left) vs. LEDAPS atmospherically corrected surface reflectance imagery (right).

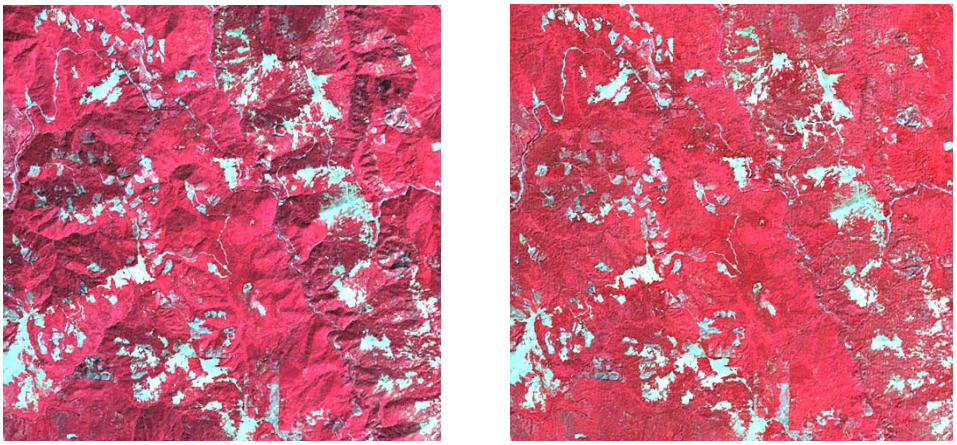
*Topographic Correction*

The study area's variable topography and sun angle at the time of image acquisition complicated automated forest detection. Forests located on the sun-facing southern side of a slope appeared much brighter in the imagery than did similar forests on the shaded northern sides of the same slope. Because the surface reflectance values of similar forests in a given Landsat scene differed greatly depending upon slope and sun angle, we were unable to automatically identify forest areas with the Vegetation Change Tracker algorithm (VCT, subsequently described in more detail). We used an experimental NASA program to normalize the illumination of each Landsat scene to approximate an ideal, direct overhead zenith-angle light source (Figure 11). This program combined the LEDAPS surface reflectance imagery, a corresponding 90 meter resolution digital elevation model (DEM), and ancillary data concerning the Landsat satellite location at the time and date of image capture in order to produce terrain/illumination corrected images. While the program did generally reduce the effects of terrain and sun angle illumination in the Landsat scenes, it also introduced erroneous pixel values

into the scenes' steepest areas. We speculate that these erroneous pixel values are due at least in part to the 90 meter resolution DEM from NASA's Shuttle Radar Topography Mission (SRTM)(van Zyl, 2001) having too coarse a resolution to accurately model the elevation changes captured in the 30 meter resolution Landsat imagery. Additionally, we found that these terrain/illumination corrected images lowered the accuracies of our forest change detection methods (described below in greater detail) when compared to the imagery only corrected for atmospheric aberrations. As such, we proceeded in our analysis using imagery that was not topographically corrected.

**Figure 11: Landsat imagery shown in a Band 4-3-2 combination.**

**No Terrain/Illumination Angle Correction** **Terrain/Illumination Angle Correction**



The left image is not corrected for terrain and illumination angle effects, and the right image is corrected.

*Cloud masking*

Persistent cloud cover during the growing season also impeded deforestation analysis. Because many Landsat images were partially obscured by cloud cover, we employed a cloud detection and masking algorithm to limit the possibility that clouds and cloud shadows would be misinterpreted as forest disturbance by the forest change detection algorithm. Cloud detection and masking algorithms rely upon clouds' distinctive spectral and physical characteristics to automatically identify clouds and cloud shadows in an image and create a new "cloud mask" image indicating the location of clouds and cloud shadows. These cloud mask

images can in turn be applied to the original cloud-filled imagery to create a cloud-free image having “no data” values in the place of the masked-out clouds. We compared five different automated cloud masking algorithms to determine the most accurate algorithm for the study area. The aforementioned ACCA algorithm was designed to be a computationally efficient method to estimate total cloud cover in a Landsat scene and produce a binary cloud/cloud-free mask image (Irish *et al*., 2006). The Vegetation Change Tracker (VCT) deforestation detection algorithm includes a cloud detection algorithm that produces a more sophisticated cloud mask that discriminates between clouds, cloud edges, cloud shadows, and cloud-free areas (Huang *et al*., 2009). The Function of Mask (Fmask) algorithm uses image segmentation to determine the location of potential cloud and shadow objects and produces a mask discriminating between cloud, cloud shadow, and cloud-free areas (Zhu and Woodcock, 2012). Our comparison showed Fmask to be the most accurate cloud detection algorithm (Figure 12Figure 12).

**Figure 12: A comparison of Landsat imagery to the ACCA, VCT, and Fmask cloud-detection algorithms**

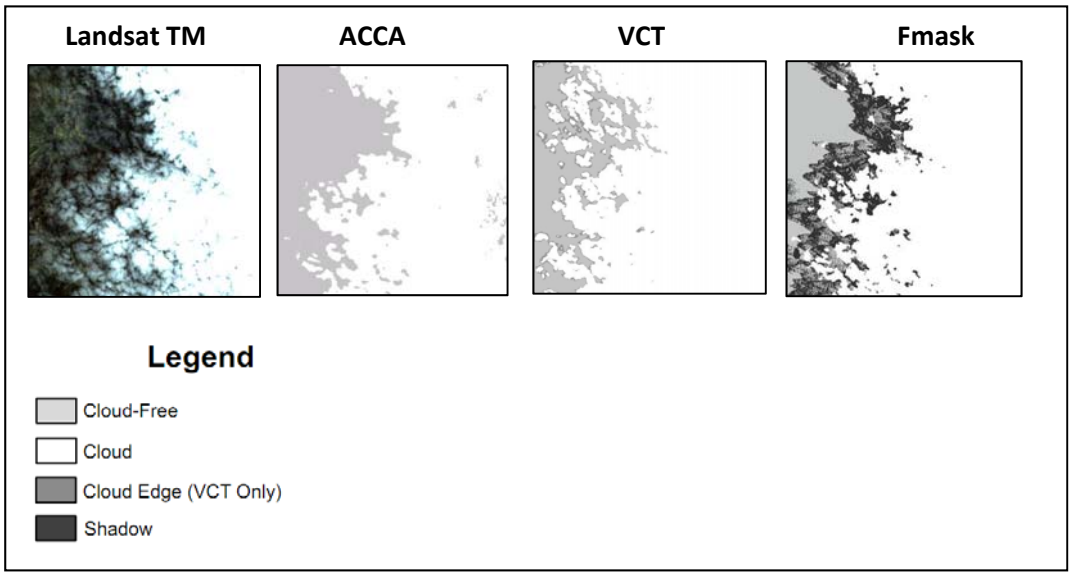



*Image Compositing*

In cases where there were no cloud-free Landsat images for a given growing season in the study areas, we produced composite images of cloud-free pixels using the aforementioned cloud masks. VCT automatically produced cloud-free composite images for each growing season in the study areas, but too often these

composites erroneously included cloud pixels. As a result, we wrote a compositing program which combined the atmospherically corrected Landsat images along with their corresponding Fmask-generated cloud masks to create cloud-free imagery for each growing season in each study area.

**Automated Classifications**

Once we had completed the previous steps of atmospheric correction, cloud detection and masking, and the creation of cloud-free composite images, we used both automated and manual deforestation detection methods to determine the time and location of forest change in the study areas. VCT automatically detects forest location in each VCT-generated annual cloud free composite image based upon the distribution of surface reflectance values in the image. VCT generates a local image window (e.g., 5km by 5km) that moves through the image and analyzes each resulting histogram for band 3 (0.63 – 0.69 micrometers), the band in which forest pixels are most easily delineated from non-forest pixels (Huang *et al*., 2008). If a local image window has a sufficient proportion of forest pixels, these pixels will form a "forest peak" in the lower range of the reflectance values in the histogram and indicate the location of probable forest pixels (Huang *et al*., 2008). Because this forest peak is identified individually for each image through an analysis of its local image window histograms, this forest identification method is theoretically insensitive to spectral variations between images due to vegetation phenology, atmospheric conditions, and illumination geometry (Huang *et al*., 2008). VCT compares the probable forest pixels against an existing landcover product to ensure that it hasn't over-identified the quantity of forest in each local image window (Huang *et al*., 2008).

For our analysis, we used the Mexican Instituto Nacional de Estadistica Geografia e Informacion (INEGI) Serie IV landcover map from 2010. Also, in order to exclude non-forest pixels located in the forest peak by virtue of their low reflectance values in band 3 (e.g., water, dark soil, burn scars), VCT identifies and masks out all pixels having a Normalized Difference Vegetation Index (NDVI) value of less than 0.2 (Huang *et al*., 2008). Once VCT determines the location of forest/non-forest for each annual cloud-free composite image, it compares these images to prior and following years' forest distributions to determine the locations of annual forest disturbance. For instance, if a 1998 composite image determines a particular pixel to be a forest pixel and a 1999 composite image determines that same pixel to be non-forest, VCT marks the pixel as "disturbed forest" in 1999. VCT generates annual forest disturbance images for each year of the analysis showing forests disturbed during the year in question, forests previously disturbed during the analysis, and forests not disturbed during the analysis (Figure 13). We tested VCT on Landsat footprint W2 Path 046 Row 029 in Oregon, Unites States with satisfactory results (Figure 14). However, VCT produced unsatisfactory

results in the Mexico study areas. We found that VCT's automated forest detection algorithm consistently undercounted forest in the study area and thus could not produce accurate maps of annual forest change. This may be because VCT's band 3 forest peak detection method is not as suitable to Mexican forests compared to the temperate Northern forests upon which the method has been more extensively tested. Additionally, VCT was unable to satisfactorily manage data inconsistencies related to the 2003 scan-line corrector failure on Landsat 7. Tests of VCT which included Landsat 7 data with the scan line error showed erroneous disturbance pixels which were simply the result of misinterpreted scan line errors (Figure 15). Because VCT's automated forest detection algorithm did not produce satisfactory results in Mexico, we transitioned to a manual forest classification and deforestation detection method.

**Figure 13: VCT annual forest disturbance map**

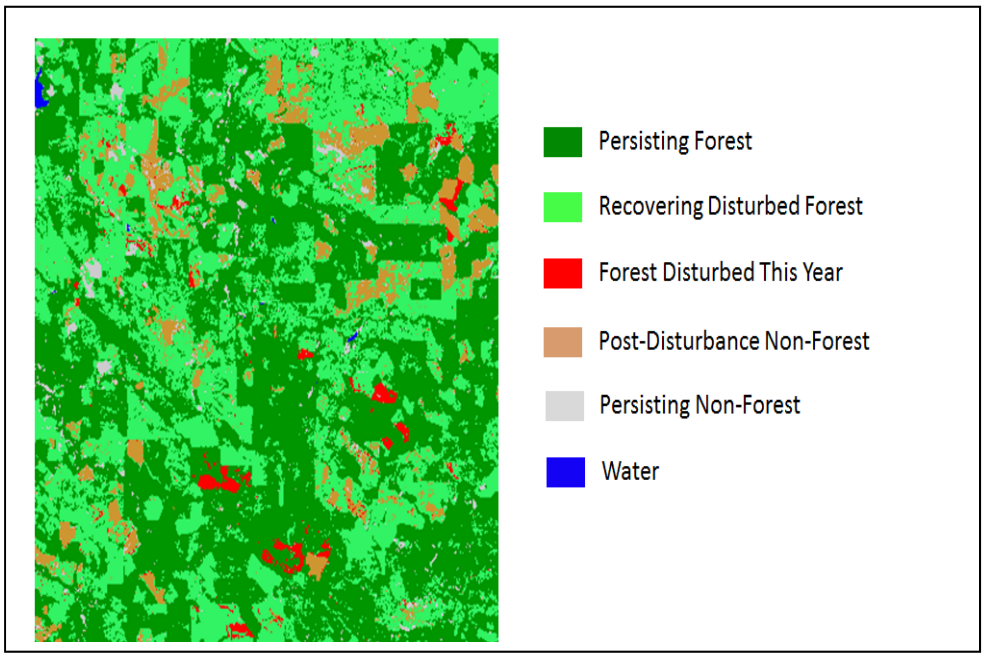
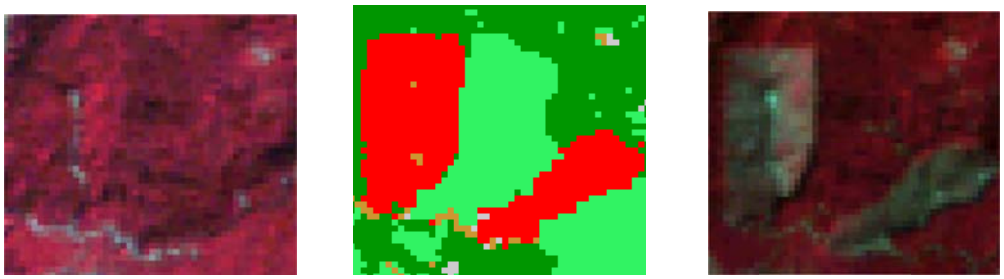


**Figure 14: A comparison of VCT's 1990 forest disturbance imagery (center) to band combination 4-3-2 imagery from 1989 (left) to 1991 (right)**

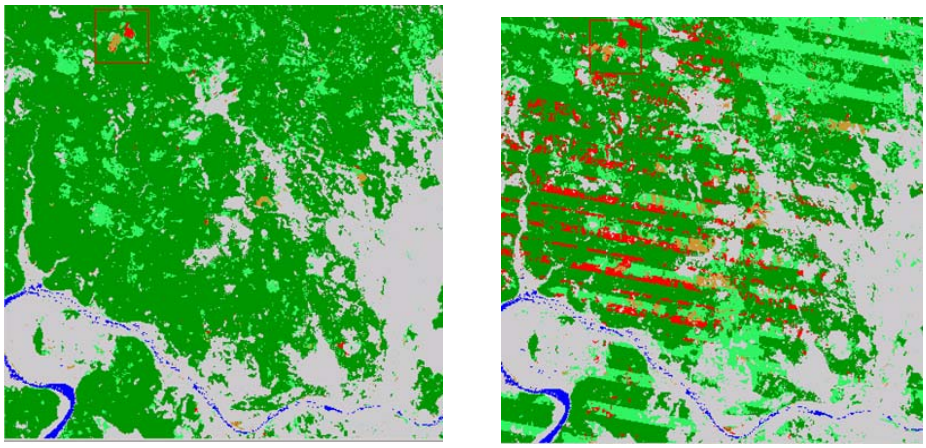
**1989** **1990 Forest Disturbance** **1991**



The areas in red in the 1990 disturbance imagery indicate forest that was disturbed in 1990, which can be confirmed by comparing the 1989 and 1991 imagery. These images are from Oregon, where VCT performed satisfactorily.

**Figure 15: A comparison of 2008 forest disturbance images for Mexico wherein the input dataset included only data from the Landsat TM sensor (left) and the Landsat TM and ETM+ sensors with the scan line corrector (SLC) error (right)**

Landsat TM Landsat TM and ETM+ SLC-off



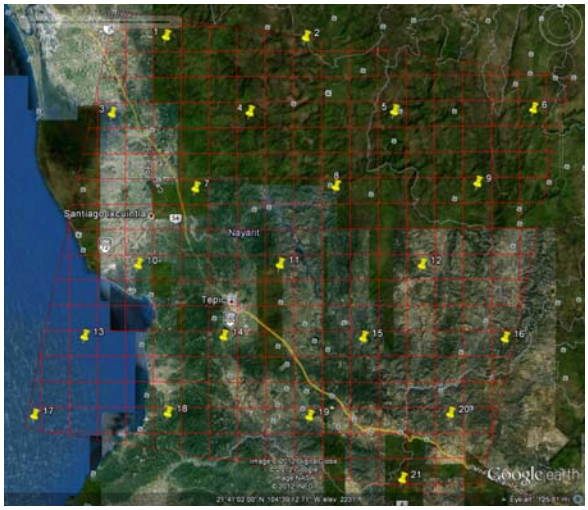
VCT misinterprets the scan lines in the input imagery as representative of forest disturbance, greatly exaggerating the apparent amount of forest disturbance in the image.

maps in order to minimize cumulative errors over time. We used non-parametric Support Vector Machines (SVM), a manual approach, to detect deforestation. This promising machine learning technology has been successful in remote sensing and has also been tested in steep conditions (Kuemmerle *et al*., 2009). The Support Vector Machines maximize the separability of the classes using a set of training points. We obtained the training points by using a multiple step classification approach. We started by running the ISODATA unsupervised classification on the most recent image of each of the Landsat footprints. This classification was set to generate 50 landcover classes. These classes were then grouped to a rough binary forest/non forest raster. This raster was then used to obtain 500 random points within the forest area and another 500 points on the non-forest areas. The points were then checked visually for consistent landcover type (forest or non-forest) both in the Landsat images of 1990, 2000 and 2010 and Google earth imagery. Points where the landcover changed within these time periods were eliminated from the dataset, leaving only points that consistently presented the same land cover over the tree dates as training points. With this final training dataset we ran the SVM tool in ENVI using the image composite produced previously for individual years in the 1990-2010 period as inputs.

*Accuracy Assessment*

The accuracy of the classifications was addressed using cross validation with three types of data. First, 20% of the training points taken for classification were left aside for validation. Secondly, deforestation polygons obtained using multi-year high resolution imagery available in Google Earth. Thus far, footprints 033041, 032041, 032042, 030044, 020046, 025048, and 027045 have been examined for deforestation patches. As this procedure is labor-intensive, consecutive footprints are being analyzed only in systematic sample of the total Landsat footprint area (Figure 16). Manually digitized deforestation polygons are registered in KML files in Google Earth and then converted into ESRI shapefiles to be integrated with the GIS database. Because the high resolution imagery used to find deforestation polygons is captured on various dates even within a single Landsat footprint, for each deforestation polygon we have recorded the date of high resolution most closely preceding and following the deforestation event (e.g., a 2003 pre-deforestation date and a 2005 post-deforestation date) (Figure 16). Thus we can use these polygons to assess the accuracy of classification for the years in which we observed the changes for the years in which Google Earth provides high resolution imagery. The last verification dataset was obtained by the enumerators around the properties surveyed during 2011. These points consist of pictures and records of the landcover in random points in and outside the applicant properties of the PES in 2008.

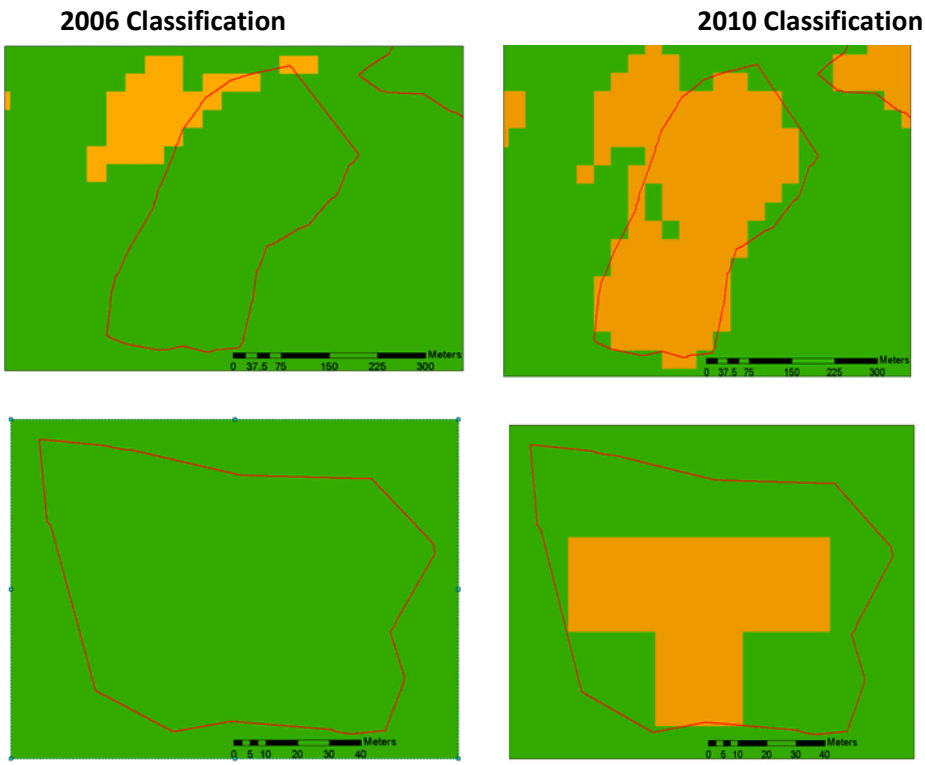
**Figure 16: Google earth image showing the sampling grid of the 033041 footprint**




Yellow pushpins indicate the quadrats selected for searching deforestation areas.

Our preliminary results in the footprint 033041 in northern Mexico show a surface of approximately 60% occupied by forest. Our classification accuracies ranged from 70.2 to 75.1% for individual years. These accuracy levels are lower than expected—a recent analysis of land change in Russia using the same type of Landsat data and methodology reached accuracies above 90%, though it had the benefit of more Landsat data and fewer issues with perennial clouds. Thus far we have been able to increase classification accuracies 2% by including elevation and hillshade data derived from SRTM imagery, and we are experimenting with other dataset combinations to further increase accuracy. We have identified classification errors resulting from the inclusion of Landsat 7 ETM + data having the scan line error; radiometric differences between Landsat 5 and Landsat 7 imagery captured at different points in the growing season appears to have confounded the classification algorithm. Classification accuracy was also reduced by the variable lighting conditions on Mexico's rough topography, as well as atmospheric haze not recognized by the cloud detection and masking algorithms. One of the more persistent classification errors was the misclassification of topographic shadows and haze-covered areas as non-forest. Further analysis will focus particular attention on the effects of topography on classification accuracy.

**Figure 17: Detail of classification forest (green) and non-forest (yellow)**




The redline shows the digitized deforestation polygon using Google earth.

*Trajectory analysis*

Having produced the final forest non-forest maps for individual years, we applied image operations to obtain the differences between two contiguous images in time to detect deforestation and afforestation. We performed a trajectory analysis to eliminate false changes in the deforestation analysis, discarding as spurious land changes all pixels that changed categories for one year (e.g., a hypothetical pixel that was forest between 2000 – 2005, apparently non-forest in 2006, and then forest again from 2007-2010). We assumed that a pixel indicating deforestation should to be classified as non-forest for at least 3 years following the deforestation event. This method of trajectory analysis has the added benefit that single-year gaps of pixel-level data are not as detrimental to the final data product because data for a single year is insufficient to indicate land change. This analysis will produce annual and aggregate deforestation maps for each footprint. Thus far we have conducted the trajectory analysis on footprint 033041 and found the

average annual deforestation rate to be less than 0.3%.

**SUMMARY**

The Landsat analysis has been fraught with difficulties due to the topographical and phenological complications of Mexico, in addition to what appears to be a falling rate of deforestation in recent years (an average annual rate of less than .3%). We are moving forward with the Landsat analysis using a combination of manual classification and Support Vector Machines.

# PART IV. PRELIMINARY RECOMMENDATIONS AND ANSWERS TO KEY QUESTIONS POSED BY CONAFOR

## Section 1: Selection of possible socio-economic indicators for monitoring

One question that has arisen in several conversations with program managers at CONAFOR is the possibility of collecting data for on-going evaluation of socio-economic impacts of the program. Our results have shown that, on average, there is not a tremendous impact, although there is some heterogeneity in this impact. This is good news in the sense that one can say with confidence that the program is not hurting the poor, particularly in terms of food security or participation in agricultural and livestock activities, which has been a theoretical criticism of PES programs. There seem to be some changes in crop structure and investment that might lead to longer-term, positive impacts of the program through intensification of production. Further monitoring could allow for deeper understanding of the longer term impacts of this process. In this section we propose two different ways in which one might monitor the on-going impacts of the program, perhaps with an eye toward looking at outcomes over the longer term. We have ordered the possibilities in terms of increasing cost of implementation as our experience running the survey reinforced the already well-known difficulty of collecting careful and accurate data in rural locations at low cost.

### *1. Rely on locality level information collected by CONAPO*

The Consejo Nacional de Poblacion (CONAPO) collects information on key indicators at the locality level every five years. The lowest-cost effort that CONAFOR might use to monitor socio-economic impact is to use this secondary data to measure on-going program impacts. A most basic analysis could use the marginality index as the main outcomeWhile as we have seen above, the program may have impacts on a variety of outcomes, marginality is the one of primary concern for policymakers in Mexico. Comparison between changes in marginality outcomes over 5 year blocks of time in beneficiary and rejected properties could provide a good proxy for program impact. More specifically, the locality will be the unit of observation in this analysis and localities will be classified as treated if they have a beneficiary property within their boundaries or untreated if they have a rejected property. The calculation would need to be conducted as follows:

(1) $(IM_b^1 - IM_{nb}^1) - (IM_b^0 - IM_{nb}^0)$

Where *IM* is the mean value of the marginality index for beneficiaries (*b*) or non-beneficiaries (*nb*), before enrollment in the program (0) or after enrollment in the program (1).

Ideally, the non-beneficiaries chosen for comparison should come out of the pool of rejected applicants, and should be as similar as possible to the beneficiaries before enrollment in the program. This metric of "similarity" could be as simple as finding a non-beneficiary with the same initial level of marginality ($IM_{nb}^{0}$=$IM_{b}^{0}$), or as complex as using the scores which are currently calculated to evaluate applicants. There are two possible complications with this approach. The first one is that this calculation will reflect a "longer term" impact for some beneficiaries but not for others. Take, for example, a beneficiary enrolling in 2012. Socio-economic impacts for this beneficiary would be calculated using information from 2010 and 2015, reflecting changes induced by the program over the three years since its enrollment. Impact for the 2014 cohort, however, would use these same outcome measures, but the program would have had only 1 year to establish impact. The second limitation is that it is possible that within a locality we have multiple beneficiary or non-beneficiary properties. This will probably be the case for private propertiessince each landowner is a very small part of a locality. If this happens, one would need to make adjustments to reflect the number of properties in a particular locality enrolled in the program instead of classifying the locality as treated or untreated.

***2. Survey a small sample of beneficiaries and non-beneficiaries***

A second possibility is to have CONAFOR technicians conduct periodic surveys in beneficiary *and non-beneficiary properties.* We cannot emphasize enough the importance of having a non-beneficiary group with which to compare the beneficiaries. As we have shown several times in this report, it is extremely misleading to claim impact from the simple change in beneficiary outcomes over time, or from the cross-sectional variation in outcomes between beneficiaries and non-beneficiaries. This is because manyother factors are changing over time, including migration trends, production possibilities, market prices, etc. Having attempted to track down communities and households rejected by the program, we recognize that this is not always an easy task, given some of the hostility generated by the rejection process. One possibility would be to provide some small compensation for surveyed non-beneficiary households, or additional help towards a future application to a CONAFOR program.

Difficulties of inducing non-beneficiary participation aside, we would recommend the following process for a survey of this type.

a. At the time of application (before program implementation) baseline surveys should be completed. In communities, a random sample of 5 households should be surveyed. This could be done by a CONAFOR

representative or forest technician using the list of community members.[30] Since many applicants do not approach the CONAFOR offices directly but only the técnico, one possibility will be to require that these surveys be part of the application process. To make sure surveys contain the responses of actual households, some type of random monitoring and enforcement should be established. For this, CONAFOR employees will have to interview again to a much smaller sample of households during their ground visit to verify that they actually responded to the original surveys.

b. The set of outcomes used to assess household wealth could minimally include: floor type, possession of refrigerator, car, computer, and the number of rooms in the house. Another possibility would be to limit the collection to the assets generally used by CONAPO: % household literate, % household with primary education; if the household has a toilet, electricity, piped water, dirt floor, refrigerator, and household size.
c. A secondary set of outcomes focused on labor and production might include the primary source of income for the household, and, if that income comes from agriculture, include area cultivated, 5 most important crops, number of large animals, and area used for grazing. The survey should be field tested and designed to take no more than 10 minutes to complete. We believe that this type of rapid response survey is more likely to be feasible for CONAFOR to conduct internally at low cost.
d. The same survey should be given as a follow-up every two to three years to the same beneficiary households and a selected group of "similar" non-beneficiaries, selected based on the outcomes of the baseline surveys. Once beneficiaries are selected, the sample for follow up surveys can proceed as follows:
    i. For each regional office, randomly select 10% of the beneficiaries for follow-up.
    ii. For each selected beneficiary, locate a non-beneficiary (using the survey database) with similar characteristics
    iii. Apply follow up surveys to this population.

[30] More specifically, this random sample could be selected from the padrón or acta de asamblea that each community submits during the application process. To avoid leaders or técnicos choosing which households should fill out the survey, CONAFOR should clearly establish the names of those households that need to be interviewed selecting them randomly from the list. For example, if the total population of ejidatarios is 50, we should divide this by 5 and then select households in positions that are multiples of 10 (50%5) (i.e. 10, 20, 30, 40, and 50). The assumption is that the order of the list follows an alphabetical order.

e. Undertake the calculation outlined in equation (1) for each of the outcomes of interest.

f. In beneficiary common property communities, it may also be important to ask both leaders and households how payments are being distributed. The information collected from household surveys could help confirm whether the flow of payments described by the leaders is similar to the perception of the households.

We believe that it is feasible to conduct a relatively low cost, continuous evaluation of the socio-economic impacts of the program. However, it is very important to recognize that such an evaluation could never come at zero cost. Our recommendations include an activity – collecting household surveys, that, while it need not be time consuming, is an additional activity for either tecnicos or enlaces. As such, it may be necessary to incentivize the baseline survey by formalizing it within the rules of operation. It is highly unlikely that the exercise will be useful unless it is done properly. In particular, it is essential that tecnicos receive some training in both the selection of the surveyed households, and the implementation of the survey.

Evaluation information will be most useful if databases are kept current and organized, and if there is sufficient follow-up of the both tecnicos and enlaces to ensure timely application of surveys. For this reason, we strongly recommend supporting staff dedicated to this activity in the central CONAFOR office and providing sufficient funds to support database maintenance, including travel to both regional offices and program applicants.

## Section 3: Selection of properties for control purposes based on a stratified sample

When evaluating a PES program, typically only a subset of properties can be monitored, especially if monitoring requires purchasing high-resolution satellite imagery. The question is how to select properties so that a reliable estimate for each forest types can be made, but also so that the overall estimate is most accurate.

In order to obtain the best estimate for each forest type, it would be ideal to monitor the same number of properties in each forest type. Such a sampling design may be referred to as ‘equal allocation’. However, equal allocation would not lead to the best overall estimate because there are more enrolled properties in some forest types than in others. A stratified sample would result in a better estimate of the overall deforestation rate. This can be best illustrated with an example, and we chose 2009 to illustrate our point (Table 41).

**Table 41: Example of an unstratified sample optimized to get the best estimate for each individual forest type, and a stratified sample, based on the proportion of each forest type in the overall enrolled area.**

| Forest type | Unstratified sample (no. of properties) | Area of enrolled properties ($km^2$) by forest type | Proportion of the area enrolled in each forest type | Stratified sample (no. of properties) |
|---|---|---|---|---|
| Evergreen | 17 | 1417.4 | 0.46 | 46 |
| Oak | 17 | 375.4 | 0.12 | 12 |
| Cloud | 17 | 330.8 | 0.11 | 11 |
| Tropical deciduous | 17 | 335.5 | 0.11 | 11 |
| Tropical evergreen | 17 | 326.10 | 0.11 | 11 |
| Tropical sub-deciduous | 17 | 292.6 | 0.10 | 10 |
| All forest types | 102[1] | 3077.7 | 1.00 | 100 |

[1] this number exceed 100 because of rounding

Let us assume the goal is to evaluate deforestation on the 420 properties that were enrolled in 2009. Of these, 343 were located within the boundaries of a forest ecosystem, and we focus in our example on these 343 properties. Let's also assume that funding is available to monitor 100 properties. Given that there are six forest types ('ecosystems'), an equal allocation would select 17 properties in each forest types. Such a sampling design would provide a great estimate for each forest type, but not the best estimate for the enrolled properties as a whole.

The reason that an unstratified sample would not provide the best overall assessment is that evergreen forests represent a much larger share of the overall area that is enrolled than any other forest type. In fact, evergreen forest represents almost half of the overall enrolled area. Allocating only 17 (one sixth) of the properties to be selected for deforestation monitoring in almost half of the enrolled forest area is not ideal.

The stratified sample that is based on the proportion of the area enrolled will do a much better job, because it selects 46 of the properties enrolled that are in evergreen forests, and that is the forest type for which it is most important to have a very accurate measurement. Also, the beauty of such a stratified sampling design is that it is easy to calculate the overall error from the full sample. The equal-allocation sample requires an adjustment for the fact that less-enrolled forest types were sampled just as much as the more-enrolled types.

However, putting more selected properties into evergreen forests means that there are less for all the other forest types. For example, for cloud forests, the number drops from 17 to 11, and that means that the estimate for cloud forest by itself is not as accurate. That is the trade-off.

A few other considerations, in addition to the sampling design:

- The amount of sampling effort, i.e., how many properties to select for checking, depends on two factors: a) the desired accuracy of the estimate, and b) the resources available for checking. Our sense is that rates of deforestation on enrolled properties are very low. That is good from a program perspective, but bad from a sampling perspective. For example, if only 5% of the enrolled are deforested, then the sample for a given forest type would have to be at least 20 to be able to detect that at all, and realistically two to three times that much to have a robust estimate. We realize that that would mean selecting a very large number overall though, and in some forest types all the properties that are enrolled.
- In order to evaluate the program, it would be ideal to monitor not only enrolled properties, but also unenrolled properties. From a statistical viewpoint, it would be best to have the same sample size in each category, but that would double the number of selected properties. Again, feasibility will have to determine what can be done.
- In prior discussions, there was a desire to have not only estimates for each forest type, but also for each administrative region. In principle, it is not a problem to design a sample to obtain robust estimates for both regions, and forest types. Indeed, it would even be possible to obtain a robust sample for each forest type in each region. However, the number of properties that would have to be selected increases very rapidly when stratifying by multiple factors (forest type and region).
- Once the number of properties for each forest type has been identified, it is highly desirable to select the properties that will be checked randomly. A simple way to do so is to list them in EXCEL, and then to have a column with random numbers next to the column of property IDs. The function =rand() provides random numbers. Once each property has been assigned a random number, then they should be ranked based on the random number, and the properties with the smallest random numbers should be selected for checking until the desired number has been selected.

In summary, stratifying the sample of selected properties is in all likelihood the best route to go to ensure the best possible estimate of overall deforestation rates of enrolled properties. The stratification should be based on the proportion of the area of each forest type in the overall area that is enrolled. The total number of properties to check depends on feasibility and desired accuracy. The actual properties to monitor should be picked randomly.

## Section 4: Environmental benefits, opportunity costs, and targeting

As discussed above in section IV.1, it would be difficult to further modify the program targeting strategy in order to simultaneously achieve jointly the goals of forest conservation and poverty alleviation. The one exception to this is potentially augmenting the amount of payments going to common property communities, given that they are both relatively poor and have a higher tendency towards deforestation than the private properties. We are cognizant of the fact that the program has already been combined with other PES programs managed by CONAFOR, and we applaud this interest in harmonizing criteria and potentially minimizing the administrative burden of these programs by conducting all of the resource allocation activities within one exercise.

Conceptually, one can think of the actual payment for environmental services as compensating the owner for, at a minimum, the opportunity cost of the land enrolled (the foregone profits from that land) plus the direct costs of participating, and at a maximum for the environmental benefits from that land which accrue to society as a whole. This statement has two implications for the setting of payment rates:

1. If landowners are not sufficiently compensated for what they would have otherwise earned using the enrolled land and time devoted to forest management, they will not participate.
2. From an economic perspective, it is not "efficient" to pay landowners if the environmental benefits of their participation are less than their opportunity cost. .

For all practical purposes, however, it is extremely difficult to measure "environmental value." Given this reality, the most cost-effective way of allocating payments in environmental programs is to calculate some measure of environmental benefits, and some measure of opportunity cost, then give each property a score based upon the ratio of benefits to cost. Properties with the highest benefit to cost ratio should receive payments first. This is similar to the methodology used by the US Conservation Reserve Program in the targeting of their program (http://www.ers.usda.gov/topics/natural-resources-environment/conservation-programs.aspx).

One of the complications here is that, theoretically, this ratio is undefined for forest with no anticipated use (in other words, an opportunity cost of zero). An alternative solution, which also avoids the problem of spending large amounts of money for environmental services that were never at risk of being lost in the first place, is proposed in Alix-García, de Janvry and Sadoulet (2004). These authors suggest that weighting the environmental benefits by the risk of deforestation, thus creating a measure of "expected benefits," can help circumvent

this problem. In essence, this assumes that the risk of deforestation is correlated with opportunity cost, so risk is used as a proxy. CONAFOR already uses INE's risk of deforestation layer to help target its payments, and in this sense partially satisfies this criterion. In addition, the existing layer used for establishing deforestation risk is now getting somewhat older, and it might be useful to update this tool using the existing Monitoreo de Deforestacion.

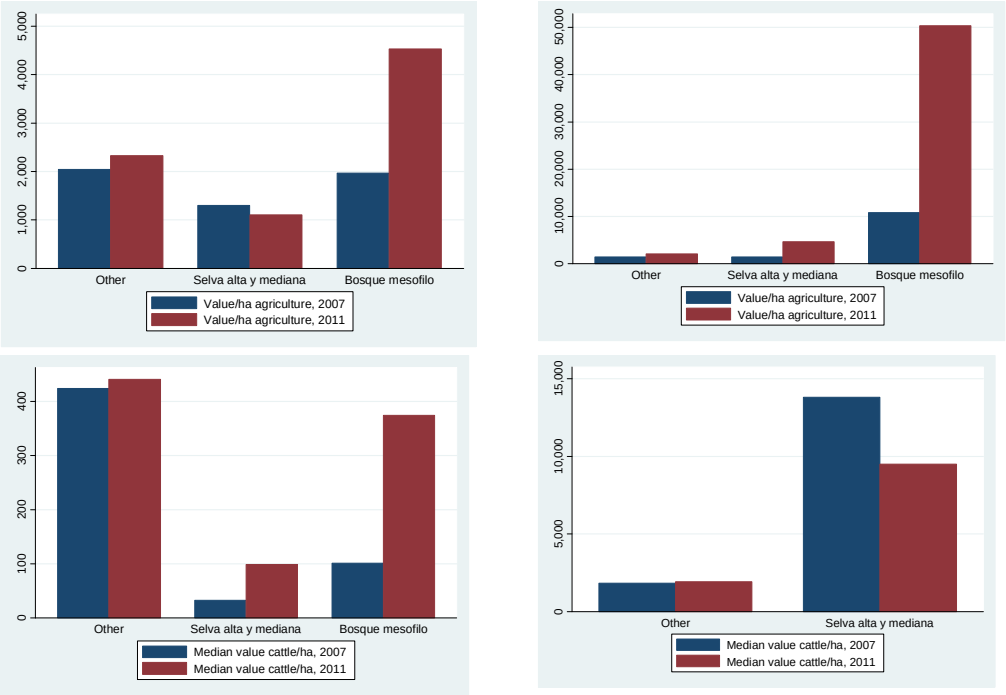
*Revenues and the current payment scheme*

The component of the 2010 targeting criteria that only corresponds partially to the guidelines presented here is the levels of the differentiated payments. The payment values themselves seem to be correlated with perceived environmental benefits rather than with opportunity costs. Our survey does not give us the information necessary to calculate opportunity costs of the land enrolled in PES. This calculation will require a lot of information and involves several complexities. Opportunity costs need to include all of the profits foregone from not using the land for other activities. The calculation of profit requires both revenues and input costs for expected land uses. Our data provides, for agriculture, pastoral activities, and forest extraction, an approximation of revenues (quantity of production multiplied by prices), but we have no way to approximate input costs, which would require significant field work in order to detail the labor inputs used in the production of the goods in question. In the following paragraphs, we examine the correlations between the current targeting scheme and these values, and then examine the variation in these values across regions. Because we do not find large program impacts on the benefits generated from agricultural or pastoral production, we include in this presentation statistics from beneficiaries and non-beneficiaries aggregated together. We do not include values from households that do not engage in these types of production.

Figure 22 below shows median values by enrolled forest type for those who engage in agricultural and/or pastoral production. It is not clear, in our data, that the highest payments are being given where alternative values of the land are the highest. If this were the case, we would expect the level and growth of agricultural and pastoral yields to be highest in areas with cloud forest, then in areas with rainforest, and finally in other forest types. On the left panel of the graph we observe the values for ejidos, and on the right for private properties. Agricultural revenue growth was indeed highest in both private and communal properties that enrolled at least some cloud forest. However, in the ejidos, where the vast majority of residents engage in agriculture, the levels and growth of agricultural production in the lowest paid category of forest are higher than for those enrolling rain forest. The level of pastoral production is also quite respectable for these properties, although it does not appear to be growing as fast as it is in the rain and cloud forest properties. Among private properties, none of

those enrolling cloud forest engage in cattle production, and the growth of cattle production in rain forest areas seems to be decreasing.

**Figure 18: Median values of agricultural and cattle production by enrolled forest type**




**Ejidos** **Private properties**

Median values only include those households participating in agricultural or pastoral activities. On average, more than 80% of common property households engage in agriculture, and 25% have cattle. For private properties, only 55% engage in agriculture and 36% have cattle.

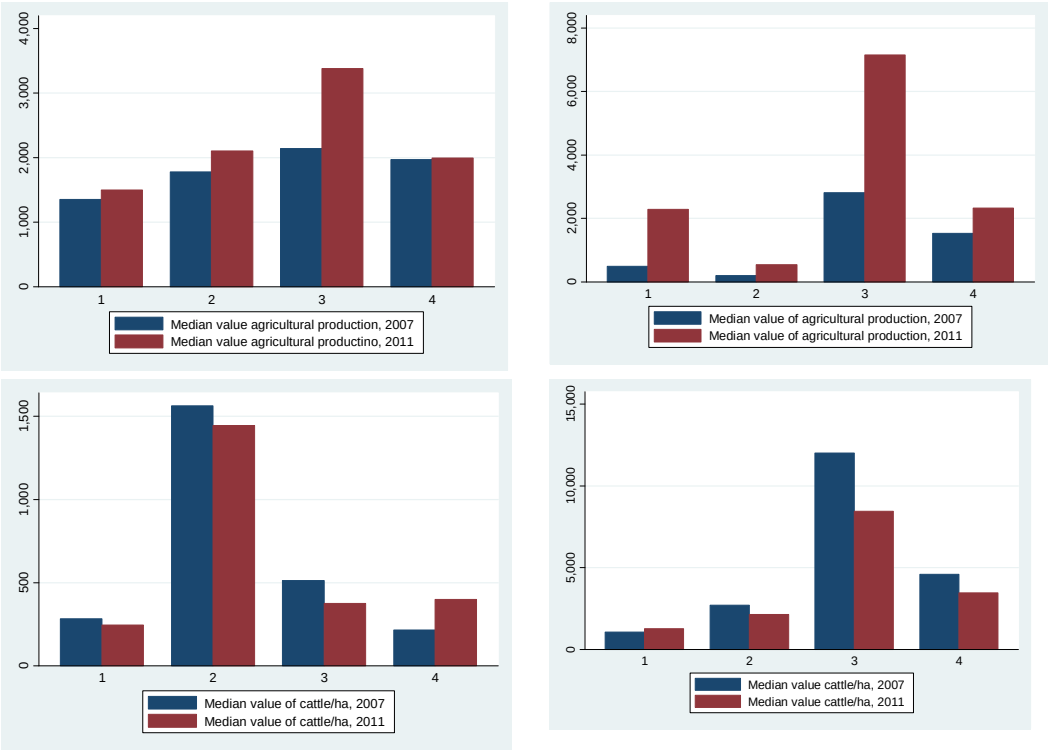
We would like to spend more time analyzing this information in order to provide a clearer assessment of the relative payment sizes. However, given the current statistics by forest type, it appears that while the higher payments to cloud forest are warranted from an opportunity costs perspective, it is not clear that such a generalization is possible for the relative difference between rainforest and coniferous/oak forests. The numbers overall suggests that payment rates might be set somewhat low – the median value of agricultural production per hectare (from Part II above) is $1891 for ejidos in 2011, and even higher for private properties engaged in agricultural activities. Two caveats to this statement are: 1) the number does not take into account costs of production; and 2) it is not clear that the land enrolled in the program is of the same quality as the land which individuals are currently farming. In fact, it is highly likely that the enrolled land has lower productivity possibilities.

A payment rate criterion that might correspond most closely to the framework above would be payments set at approximate values of alternative land uses, either agricultural or pastoral. The analysis in the previous section suggests that there is significant heterogeneity in revenues across regions, and this might possibly be an important way to stratify payments as well. We would recommend using information collected by researchers at the Universidad Autonoma de Chapingo, and the associated Centros Regionales. The data that we have thus far analyzed in our survey shed light only on the revenue side of agricultural and pastoral production, and it is necessary to understand costs in order to truly generate appropriate payment rates. Further analysis with more detailed data will be useful in helping to refine the levels of compensation for the program.

*Regional variation in revenues*

There seems to have been some sense, in our conversations with individuals from both the regional and the central CONAFOR office, that the variation in opportunity costs across the country has implications for the functioning of the PSAH. For this reason, we briefly examine the levels and growth of agricultural and pastoral revenues across regions. The median values per hectare for agriculture and cattle in 2007 and 2011 are shown in Figure 19. Here we observe that the highest levels of agricultural production in both years are in region 3, which includes Guerrero, Oaxaca, and Chiapas. This is also the region in which values have grown the most over time. For private properties, region 3 also has the highest level and growth of agricultural revenues per hectare. It is important to note that in most regions the levels of production for private households are an order of magnitude larger in private properties (note the scale of the y-axis). It is also important, however, to recall that more than 85% of the private property adults do not work in agriculture, but rather depend upon other sectors of the economy.

**Figure 19: Agricultural and cattle values per ha, common and private properties**




**Ejidos** **Private properties**

The levels and trends in pastoral production differ in the ejidos, where the greatest amount of growth has taken place in region 4 (Veracruz, Tabasco, and the Yucatan Peninsula), while the highest level of production is encountered in region 2 (the central states south of Sinaloa, Zacatecas, Nuevo Leon, and Tamaulipas). In private properties cattle production, for those households that engage in it (around 35%) is significantly more valuable per hectare than agricultural production. As with agriculture, the most productive pastoral region for private households is region 3 (the Southwest). In all regions, the value of pastoral production has either fallen or remained the same over time for private households.

Once we have completed the detailed remote sensing analysis, it will be possible to correlate these values with a risk of deforestation in order to confirm the relationship between the two. One would expect that deforestation risk would be greater where there are higher values of alternative uses of the land. With this type of analysis in hand, it would be possible to calibrate the existing deforestation risk measurements in order to reflect this. A simple regression

analysis reveals interesting correlations between the payment criterion (forest type), regional effects, and other covariates that we expect to determine deforestation. In particular, once other variables are controlled for, municipal measures of poverty to not affect the value of output. Values are lower in areas with higher slope and elevation, and, generally, higher where road densities are higher. Regions 2 and 3 tend to have higher values of cattle production, and region 3 of agricultural production. Once we control for regional variation, having enrolled forest with cloud forest is associated with significantly higher agricultural production for private properties, and much lower cattle production for ejidos. One should consider these impacts as changes in area of cloud forest enrolled, relative to other, non-coniferous, forest. Coniferous forests are associated with higher agricultural production, but lower cattle production.

**Table 42: Correlates of agricultural and cattle revenues**

| | | Dependent variables | | | |
|---|---|---|---|---|---|
| | | Ln(agricultural value/ha) | | Ln(cattle value/ha) | |
| | | Ejidos | Private properties | Ejidos | Private Properties |
| Deforestation risk variables | Median slope (deg) | -0.000** | 0.000 | -0.058** | -0.041 |
| | | (0.000) | (0.001) | (0.024) | (0.048) |
| | Median elevation (m) | -0.023* | -0.037 | -0.000 | 0.001 |
| | | (0.012) | (0.067) | (0.000) | (0.001) |
| | Road density in 10 k buffer (km rds/ km2) | 1.877 | 7.670 | 8.312*** | -7.107 |
| | | (1.901) | (5.012) | (3.097) | (4.835) |
| Targeting variables | Proportion enrolled area coniferous | 0.534** | 0.674 | -1.296** | -0.243 |
| | | (0.243) | (0.569) | (0.537) | (0.428) |
| | Proportion enrolled area bosque mesofilo | 1.132 | 2.922*** | -7.638** | |
| | | (0.763) | (0.606) | (3.341) | |
| | Municipality poverty | -0.118 | 0.065 | -0.222 | 0.314 |
| | | (0.079) | (0.334) | (0.215) | (0.399) |
| Regional variables | Region 2 | 0.304 | -1.040 | 1.727*** | 1.764* |
| | | (0.191) | (1.067) | (0.459) | (0.906) |
| | Region 3 | 0.447* | 1.714 | 1.974*** | 3.202** |
| | | (0.237) | (1.299) | (0.638) | (1.364) |
| | Region 4 | -0.529 | 0.762 | -1.681** | 2.604 |
| | | (0.407) | (1.742) | (0.786) | (1.887) |
| | Constant | 7.992*** | 6.307*** | 7.098*** | 6.244*** |
| | | (0.320) | (1.753) | (0.765) | (1.757) |
| | N | 824 | 51 | 258 | 44 |
| | R-squared | 0.0579 | 0.4468 | 0.3948 | 0.3571 |

## Section 5: The current weighting scheme

This last section represents some reflections on the weighting scheme currently used by CONAFOR in the selection process. A first point is that these criterion change with great frequency. We have observed above that, on average, these changes have generated improvements in the targeting of the program. Over time, we see more payments going to places with higher deforestation risk and poverty. As a general observation, however, it is worth noting that it is difficult to establish separate impacts of rule changes when the rules change with such frequency; in particular, when rules change every year, it is difficult to say whether differences in impact are due to some external shock occurring at the same moment (such as changes in agricultural prices, wages, or timber prices), a peculiarity of the cohort, or to the rules themselves.

More specifically, there seems to have been a trend of adding more criteria over time in order to improve the targeting process. In principle this could result in positive changes, but it also leads to difficulties in implementation. It is therefore important that additional criterion be associated with specific program goals, and that the addition of new criterion does not undermine the potential impact of the program. The table below serves to underscore this point. The table was developed on the basis of the hydrological services criterion associated with article 14 of the 2010 rules of operation. It is probable that these rules have changed somewhat, but the general implications of this exercise remain the same. The table shows the maximum and minimum points for each criterion. It also attempts to associate each criterion with one of 4 goals: poverty, environmental quality, opportunity cost, and implementation capacity. The first two are the stated purpose of the program, and constitute measures of the "benefits", social and environmental, of enrolling particular properties. The third is associated with generating avoided deforestation impact – that is, giving a higher weight to properties with higher opportunity cost/risk of deforestation – and the fourth with giving payments to properties where contracts are more likely to be honored.

At the bottom of the table we have summed up the maximum and minimum points associated with each of the broader criterion. Working under the assumption that properties are ranked according to the simple sum of points, we begin with the observation that the maximum total points for a hydrological services property according to this schedule of points is 89, and the minimum 19. A second observation is that this system gives the highest weight (55%, to be exact) to environmental quality and the lowest points to opportunity cost. This is likely to result in the selection of properties with high environmental quality that are not at risk of deforestation.

At the very bottom of the table, under the panel heading "system with equal weights on each component, we have shown a system which allows for the same calculation of points, but gives equal weight to the categories of environmental quality, poverty, implementation capacity, and opportunity cost. To implement the equal weights, the number of points is divided by the maximum number of points possible so that each category is normalized to be between 0 and 1. Each then receives .25 or ¼ of the total weight. Note that the equal weighting system is arbitrary. It might be the case, for example, that policymakers would want to give a higher weight to poverty, or to opportunity cost. In any case, if program managers would like to broadly maintain equal prioritization under the broader categories, while allowing for the introduction of new criterion over time, they might consider using a system such as this one, which calculates a score within each of the categories, and then maintains a constant weighting system through time. This does not eliminate the possibility of introducing new criterion, for example, certified forest, but it does limit the likelihood that the introduction of these new criteria undermines the other goals of the program.

| Criterion | Max | Min | Program goal |
|---|---|---|---|
| **Social criterion** | | | |
| Ejidos never having received support from ProArbol | 7 | 0 | Poverty |
| Applications from within 100 x 100 municipalities | 5 | 0 | Poverty |
| Applications from SEDESOL priority attention zones | 3 | 0 | Poverty |
| Municipality with majority idigenous population | 3 | 0 | Poverty |
| Female applicant | 2 | 0 | Poverty |
| Stimulant to good forest management | 3 | 1 | Implementation capacity |
| **Criterion for both modalities (biodiversity and water services)** | | | |
| ANAP | 5 | 1 | Environmental quality |
| Other PSA polygons in watershed | 5 | 1 | Environmental quality |
| Ejido o comunidad with Red Vigia | 3 | 1 | Implementation capacity |
| Area of influence for local development mechanism | 4 | 1 | Environmental quality |
| Ordenamiento Ecologico Territorial | 4 | 1 | Implementation capacity |
| Deforestation pressure index | 6 | 2 | Opportunity cost |
| Natural Disaster Zone | 6 | 2 | Environmental quality |
| Georeferenced polygon | 4 | 1 | Implementation capacity |
| **Hydrological services criterion** | | | |
| % with forest cover | 5 | 1 | Environmental quality |
| Overexploited aquifer | 6 | 3 | Environmental quality |
| Superficial water availability | 7 | 1 | Environmental quality |
| Soil degradation | 3 | 1 | Environmental quality |
| Strategic restoration zone | 3 | 1 | Environmental quality |
| Biomass density | 5 | 1 | Environmental quality |
| **Actual weighting system** | | | **Implied weight** |
| Environmental quality points | 49 | 13 | 0.55 |
| Poverty points | 20 | 0 | 0.22 |
| Implementation capacity points | 14 | 4 | 0.16 |
| Opportunity cost points | 6 | 2 | 0.07 |
| Score | 89 | 19 | |
| **System with equal weights on each component** | | | |
| Environmental quality points/49 | 1 | 0.26 | 0.25 |
| Poverty points/20 | 1 | 0 | 0.25 |
| Implementation capacity points/14 | 1 | 0.29 | 0.25 |
| Opportunity cost points/6 | 1 | 0.33 | 0.25 |
| Equally weighted score | 1 | 0.22 | |

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## APPENDIX A: CONSTRUCTION OF WEALTH INDICES

We construct different wealth indices to summarize the socioeconomic status of households based on a set of variables about household ownership of several assets and characteristics of household's dwelling (floors, wall, number of rooms). As Moser and Felton (2007) indicate, there are two advantages of using an asset index in comparison to using traditional consumption expenditure data to measure household's welfare. First, there is less possibility of recall or measurement problems. Second, assets can provide a better picture of long-term living standards. Despite these benefits, the construction of wealth indices involves several challenges. In particular, we need to take decisions about how to aggregate and weight each asset. In general, an index takes following form:

$$A_i = \hat{\gamma}_1 a_{i1} + \ldots + \hat{\gamma}_2 a_{i2}$$

where $A_i$ is the asset index for household $i$, $a_{ik}$ are the individual assets $k$ that household $i$ owns and $\hat{\gamma}_k$ are the weights given to asset $k$, which we must estimate. There are several approaches to constructing these weights and each of them has it own limitations and benefits. In this paper, we adopted three different methods, trying to find an adequate balance between the limitations and how intuitive or easy to understand the measure is. We explain them in detail in this appendix.

### A.1 Inverse proportion index

This is probably one of the most simple and intuitive approaches. It is based on a method suggested by Townsend (1979) and constructs the weights as the inverse of the proportion of households that owned each asset. The assumption is that assets owned by a smaller proportion of households indicate higher wealth and, therefore, should havea higher weight. This method can only be applied to binary variables and the index takes the following form:

$$A_i = \frac{1}{\sum_{i=1}^{N} a_{i1} / N} a_{i1} + \ldots + \frac{1}{\sum_{i=1}^{N} a_{ik} / N} a_{ik}$$

where $a_{ik}$ is a binary variable taking the value of 1 when household $i$ owns asset $k$, and $N$ is the total number of households in the sample. We can see that the weight for asset $k$ in this case is given by $\hat{\gamma}_k = N / \sum_{i=1}^{N} a_{ik}$. One limitation with this method is that not all assets show a linear relationship with living standards, for example, ownership of a motorbike may tend to increase up to a certain income and subsequently decrease in richer households (Howe et al. 2008). Also, for categorical data, such as walls' material, we are using binary variables

representing the best categories; therefore, any order implicit in these categorical variables is lost.

### A.2 Price index

This method uses prices to weight assets, this means $\hat{\gamma}_k = p_k$. The index then represents the total monetary value of the household's asset wealth and it is expressed as follows[31]:

$$A_i = p_1 a_{i1} + ... + p_k a_{ik}$$

Although this approach is very intuitive it has also limitations. First, price data can be difficult to obtain, even more, local price information. Ideally, an accurate monetary valuation of households' assets will require detailed information about the date of purchase, the market or area where the asset was purchased, and the current condition of the asset (Howe et al. 2008). Second, it is difficult to impute prices for non-market commodities. As Ravallion (2011) suggests, missing prices need to be assigned on a priori grounds or estimations.[32]

### A.3 Principal Components Analysis (PCA) Index

Principal Components Analysis (PCA) was recommended as a method for determining weights for variables in a wealth index by Filmer and Pritchett (2001). PCA is a data reduction procedure, which involves extracting from a large number of variables those few orthogonal linear combinations ("principal components") of the variables that best capture the common information. The first principal component explains the largest proportion of the total variance. Weights are derived from the correlation matrix of the data and assets that are more unequally distributed across the sample will have a higher weight in the first principal component. The index is constructed in the following way:

$$Index_j = f_1 \frac{(a_{j1} - a_1)}{s_1} + .... + f_N \frac{(a_{jN} - a_N)}{s_N}$$

where, $f_1$ is the scoring factor for the first asset which is determined by the PCA procedure, $a_{j1}$ is the $j$th household's value for the first asset and $a_1$ and $s_1$ are the mean and standard deviation of the first asset over all households in the

[31] The following values were used for each good (Mexican pesos): tv 4805 , refrigerator 3969, computer 7660, car 46462, stove 3269, phone 384, cell phone 3605, room 36000, dirt floor 6000, cement floor 12000, wood/tile floor 24000, bamboo or other walls 6000, adobe or wood walls 12000, concrete or brick walls 24000. Consumer goods were priced based on reports from Mexico's "Procuraduría Federal del Consumador" (PROFECO).

[32] Consumer goods prices were assigned by a research assistant who did not have knowledge of the survey results.

sample. The main assumption in this method is that household long-run wealth is what causes the most common variation in asset variables.

PCA is designed for use with continuous and normally-distributed data; therefore, its application to discrete data, as proposed by Filmer and Pritchett, can be problematic. For example, for household dwelling characteristics, such as the type of floors, which can be recorded in a scale with $n$ categories, Filmer and Pritchett propose splitting them into $n$ binary variables. This procedure introduces distortion in the correlation matrix as variables are perfectly negatively correlated with each other. Moreover, if there is any particular order this is lost since PCA treats every binary variable in the same way (Moser and Felton, 2007). More recently, some authors have suggested the use of polychoric PCA (Kolenikov and Angeles, 2009), which improves on PCA and it is also designed for categorical data. The weights in this case come from polychoric or polyserial correlations which are maximum likelihood estimates of the correlation between unobserved normally distributed continuous variables underlying their discretized versions.

Kolenikov and Angeles (2004) argue that the gain from using polychoric correlations, which are computationally more intensive than PCA applied on ordinal data, is only related to more accurate estimation of the proportion of explained variance that PCA tends to underestimate. In spite of this, the misclassification rates, as well as rank correlations of indices constructed with these two methods seem to be not substantially different. For this reason, we construct the third index in this paper using PCA on ordered data. It is important to mention some limitations related to this method. First, it requires assumptions about how to rank different categories of the data. Second, it assumes that categories are equally spaced from each other in terms of their relationship with a household's socioeconomic status. Finally, PCA is a fairly complex method and it is likely to be difficult to understand by less technical readers. This is the reason why we also construct the price and inverse proportion index, which seem to be more intuitive.