VALORACIÓN DE SERVICIOS ECOSISTÉMICOS Y CAMBIO EN EL USO DEL SUELO. LA IMPORTANCIA DEL CAPITAL SOCIAL EN LOS ANDES PERUANOS.

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Resumen

En esta tesis se estudió el efecto de la migración temporal sobre la valoración de los servicios ecosistémicos, así como el papel del capital social en el cambio en el uso del suelo, teniendo como sistema de estudio los tunales naturales ubicados en comunidades campesinas de Ayacucho, Perú, uno de los más importantes socio-ecosistemas del área andina. Los resultados permitieron identificar y valorar los bienes y servicios provistos por los tunales, y establecer que la migración temporal tiene un efecto positivo sobre la valoración de los servicios ecosistémicos. Se definieron algunas variables *proxy* para capital social relevantes en el área andina, y se análizó el proceso de habilitación de los tunales, identificándose al número de membrecías en asociaciones y a la tasa de participación en las reuniones del comité de productores de cochinilla, como variables significativas en dicho proceso. Finalmente, se desarrolló un modelo de la dinámica del socio-ecosistema, resaltando el papel del capital social en la habilitación y su efecto posterior sobre los ingresos de los campesinos.

Summary

This thesis investigates the effect of temporal migration on the valuation of ecosystem services, and the role of social capital on land use change, in Opuntia scrublands of Ayacucho, one of the most important socio-ecosystems in the Andean area. This work identified and valued the goods and services provided by the scrublands, and evaluated the positive effect of temporal migration on the valuation of ecosystem services. Some proxy variables for social capital relevant for the Andean area were defined. The analysis of scrubland habilitation process identified the number of memberhips in associations and the rate of meeting attendance to cochineal producers committee as significant variables on that process. Finally, a model of the dynamics of this socio-ecosystem, highlighting the role of social capital on land clearance and the effect of the latter on the profits obtained by peasants, was developed.

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I) Introducción General

En los tiempos actuales, la influencia antrópica en los sistemas naturales es evidente en todo el planeta. Las relaciones entre la naturaleza y la sociedad son complejas, pues involucran un gran número de variables, muchas de las cuales son medidas con gran incerteza y exhiben dinámicas e interacciones que no permiten una separación clara entre los fenómenos sociales y biogeofisicos involucrados por lo que se requiere la conjunción del conocimiento de variadas disciplinas para la comprensión y solución de los problemas ambientales (Kinzig 2001).

Recientemente, la US National Science Foundation (NSF), identificó algunas áreas de investigación transdisciplinaria, que consideró prioritarias para las ciencias ambientales: el estudio de las normas sociales referentes al ambiente, la comprensión y predicción de cambios en el uso del suelo, la valoración de servicios ecosistémicos y el desarrollo de modelos acoplados de dichos sistemas (Ewel 2001). El análisis de la NSF propone iniciar esas investigaciones en lugares donde los seres humanos, la economía y los recursos de los cuales ellos dependen esten interrelacionados y sean fáciles de evaluar. Ello debido a la claridad en los límites geográficos y definición de los grupos humanos involucrados, la facilidad de obtención de datos socio-económicos y demográficos y la capacidad de establecer relaciones con las personas encargadas de las tomas de decisiones.

Una visión transdisciplinaria involucra la percepción de un problema no desde la perspectiva de una disciplina individual (reduccionista), o desde la conjunción de diversas disciplinas operando a la vez cada una en su dominio de interes (estudio multidisciplinario). La visión transdisciplinaria promueve la búsqueda de la solución al problema, sin establecer límites o fronteras entre las diversas disciplinas científicas involucradas en la investigación (cf. Muller 2003). El papel de la ecología en estos estudios es sin duda importante. Especialmente relevante es el aporte brindado por la ecología de ecosistemas al brindar el marco sobre el cual hacer explícito el papel de la economía y de la sociedad sobre la naturaleza y el ambiente (Pickett y Cadenasso 2002). Sin embargo, el concepto mismo de ecosistema está sujeto a diferentes definiciones y alcances. Partiendo de la premisa que ninguna definición es mejor que otra, Jax et al. (1992), resaltan la relevancia práctica de establecer una serie de consideraciones terminológicas en el estudio de los sistemas ecológicos. Su análisis muestra que en diferentes definiciones de ecosistema, el mismo término posee diferentes propiedades. Algunas definiciones se basan en supuestos que no pueden ser establecidos *a priori* sino que son el sujeto de la investigación, y en muchos casos las definiciones no tienen carácter práctico y no son utilizables para la descripción del sujeto de estudio. Su análisis concluye sugiriendo que es necesario hacer explicita la definición de ecosistema utilizada, o explicitar los supuestos o propiedades de los sistemas naturales establecidos por diferentes definiciones, que sean consideradas en la investigación.

Siguiendo esa línea de pensamiento, y sobre la base de las diferentes definiciones de ecosistema, en esta tesis se considera a los tunales naturales de Ayacucho, como sistemas que poseen las siguientes propiedades: son sistemas delimitados en el espacio y tiempo (e.g., Odum 1971, Stocker 1979); la delimitación del sistema es observador-dependiente (e.g., Tansley 1935, Stocker 1979); consisten de organismos –entre los que se encuentra el ser humano- y elementos abióticos, dependientes entre si (e.g., Leser 1984. O'Neill et al. 1996); son sistemas que se encuentran en estado de equilibrio dinámico o que se mueven hacia el equilibrio

(Jorgensen et al. 1992), y que son capaces de autorregularse (Patten y Odum 1981, Salthe 1985).

Mucha de la confusión derivada del concepto de ecosistema se debe a su carácter multidimensional (Pickett y Cadenasso 2003). Las tres dimensiones del concepto i.e. significado, modelo y metáfora, proveen distintas posiciones ante los diferentes usos que el concepto puede tener dentro y fuera del lenguaje científico, así como en la interacción con las ciencias sociales. Esta interacción esta generando muchos campos nuevos de investigación, aunque en ocasiones el marco teórico de dichas aproximaciones sea todavía bastante débil (Abel y Stepp 2003)

A pesar de las recientes sugerencias de denotados ecólogos de desechar el concepto de ecosistema debido a la dificultad de reconciliarlo con el conocimiento actual de los sistemas ecológicos como sistemas meta estables, adaptativos y capaces de operar lejos del equilibrio (cf. O'Neill, 2001), el concepto de ecosistema es todavía una aproximación conveniente para organizar el pensamiento, y como todo paradigma es el producto de la limitada capacidad de la mente humana para comprender la complejidad del mundo real. A pesar de sus contradicciones terminológicas, gran parte del marco teórico de la ecología de ecosistemas es extraido de la teoría general de sistemas y compartido con otras disciplinas como la economía y la sociología, por lo que el estudio conjunto de sistemas ecológicos, económicos y sociales puede establecerse desde el mismo marco conceptual, considerando a los sistemas económicos como dependientes de un sistema natural, que es el que proporciona recursos, asimila residuos y provee servicios ecosistémicos que permiten la vida y proveen bienestar a las sociedades humanas (cf. Daily et al. 1997).

Las funciones ecosistémicas resultado de las estructuras y procesos que ocurren en el sistema natural, proveen a las sociedades humanas de bienes y servicios ecosistémicos i.e. flujos de materia y energía provenientes de los reservorios de capital natural, los cuales influyen sobre el bienestar de los humanos (Costanza et al. 1997). Desde un punto de vista antropocéntrico, la valoración se refiere a la cuantificación del cambio en el bienestar de los humanos ante un cambio en la provisión o condición de un bien o servicio provisto por los ecosistemas (Costanza et al. 1997).

El presente trabajo de tesis se enmarca en esa perspectiva integrativa y transdisciplinaria, estudiando el efecto de la migración temporal sobre la valoración de los servicios ecosistémicos, el papel de las normas sociales en el cambio en el uso del suelo y desarrollando un modelo de la dinámica de los sistemas sociales y ecológicos, teniendo como sistema de estudio los tunales naturales ubicados en comunidades campesinas de Ayacucho, Perú (Figura 1).

Estos tunales son formaciones vegetales naturales ubicadas en laderas de las zonas andinas de Ayacucho, a una altitud promedio de 2500 metros sobre el nivel del mar, con un rango temperatura entre 11 to 24 °C y un promedio anual de precipitaciones de 745 mm distribuidos principalmente desde Octubre hasta Marzo.

La cobertura vegetal consiste en pastos de los géneros *Bouteloua, Heteropogon, Pappophorum* y *Aristida.* Especímenes de *Schinus molle* (Anacardiaceae), *Caesalpina tinctoria* (Caesalpinaceae), *Agave americana* (Agaveaceae) y cactus de los generos *Cleistocerus* y *Azureocereus,* además de la especie dominante *Opuntia ficus indica* (Cactaceae), la cual alcanza densidades de 2000 plantas por hectárea conforme se incrementa la pendiente de las laderas (Piña

Lujan 1981). Ayacucho es uno de los lugares de Perú donde existe menos información respeto a la diversidad biológica, su uso y estado de conservación. El análisis de la información disponible ha resaltado la importancia de los tunales naturales para la conservación de la flora y fauna asociadas a ellos, sin embargo no se han realizado todavía estudios específicos en dichos sistemas naturales (Torres 2001).

Figura 1. Ubicación del área de estudio.

Estos tunales naturales forman parte de uno de los más importantes socio-ecosistemas en los Andes. Las funciones ecosistémicas resultado de las estructuras y procesos que ocurren en el sistema natural, proveen a las sociedades humanas de bienes y servicios ecosistémicos i.e. flujos de materia y energía provenientes de los reservorios de capital natural, los cuales influyen sobre el bienestar de los humanos. La cobertura vegetal tiene un papel significativo protegiendo las laderas contra la erosión, y mejorando los suelos. Los tunales proveen de una gran variedad de productos no maderables como frutas y cladodios tiernos empleados en la alimentación humana, suministran forraje para ganado y materia prima para la manufactura de objetos artesanales. Además, los tunales son especialmente importantes como hospederos de la cochinilla (*Dactylopius coccus* Costa), un insecto utilizado como fuente de ácido carmínico, un colorante natural empleado en Meso-América y el área andina central desde tiempos precolombinos.

Las evidencias más antiguas del uso de la cochinilla corresponden a textiles Paracas, hallados en el desierto costero de Perú, con una antigüedad de 2000 A.C. (Saltzman 1992), mientras que las evidencias escritas más antiguas del uso y manejo de la cochinilla y los tunales, corresponden a códices Toltecas del siglo X, hallados en el sur de México (Brana 1964). La familia Dactylopiidae contiene un solo género, *Dactylopius* con nueve especies, todas originarias de América y especialistas en Cactaceas del género Opuntia. *Dactylopius tomentosus, D. confusus* and *D. opuntiae* se distribuyen en Norteamérica, mientras que *D. ceylonicus, D. austrinus, D. confertus , D. salmianus* y *D. zimmermanni* se distribuyen en Sudamérica. Solamente *D. coccus* muestra una distribución disjunta estando presente en ambos hemisferios, en el sur de México y en el area andina central. Las controversias respecto al origen de *D. coccus* terminaron cuando estudios filogenéticos mostraron que la especie pertenece a un clado sudamericano y probablemente de manera similar a otros productos fue transportada hacia Mesoamérica, donde su importancia y escasez la convirtió en sujeto de tributo por parte de los emperadores aztecas (Rodríguez et al. 2001). Durante la dominación española, la cochinilla se convirtió en el segundo producto de exportación de los virreynatos americanos después de la plata. La importancia commercial de la cochinilla se mantuvo hasta mediados del siglo XIX cuando la aparición de colorantes sintéticos, disminuyó la demanda por el insecto (Brana 1964).

En los últimos años, muchos colorantes rojos han sido prohibidos debido a sus efectos nocivos sobre la salud de los usuarios, por lo que la cochinilla y sus colorantes derivados, carmín y ácido carmínico experimentaron un importante resurgimiento. Proyectos destinados a la producción del insecto y la extracción de sus colorantes fueron ejecutados en el norte de Chile, así como también en Bolivia y Ecuador. En estos dos últimos paises como estrategia de lucha contra la pobreza. Sin embargo, la reciente caida de los precios ha afectado gravemente estos proyectos y la recolección de cochinilla, sólo es importante en comunidades campesinas de Ayacucho, donde los tunales son naturals y los costos de producción son bajos (PRA 2002).

A lo largo de los Andes Peruanos, la principal forma de organización social en las zonas rurales es la "comunidad campesina". Una comunidad es un grupo de familias unidas por lazos de consanguinidad o compadrazgo, que habitan un territorio definido. En dicho territorio, la tierra es de propiedad comunal pero, por propósitos productivos, es dividida en terrenos comunales, que son explotados en trabajo comunal obligatorio, y terrenos que son asignados a hogares individuales, los cuales son trabajados con la mano de obra familiar y aquella obtenida sobre la base de relaciones de cooperación y reciprocidad.

La comunidad es un colectivo definido, que no sólo posee dimensiones productivas, sino también provee de sentido de pertenencia e identidad a sus miembros, facilitando el compartir información respecto al entorno natural y social. Esto se ha reflejado en su capacidad de llevar a cabo acciones colectivas destinadas a mitigar el riesgo de hambruna o manejar recursos comunales, iniciativas que son asociadas con externalidades positivas consecuencia de las interacciones sociales y el capital social (Collier 2002).

Capital social es un concepto amplio que captura la idea que algunas características de la organización social tales como redes, normas y confianza, facilitan la coordinación y cooperación para el beneficio mutuo (Putnam 1995). El capital social no es una entidad única sino una variedad de entidades multidimensionales, por lo que los conceptos de Gittell y Vidal (1998), referentes al capital social *de unión* (bonding) y al capital social *de puente* (bridging) son importantes para entender que, contrariamente al capital humano el cual reside en los individuos, el capital social reside en las relaciones (Lin 2001). Así, el capital social *de unión* se refiere a los lazos entre las personas que facilitan las interacciones dentro de los grupos y las acciones colectivas, mientas que el capital social *de puente* refleja los nexos entre los grupos y otros actores u organizaciones (Narayan 2002).

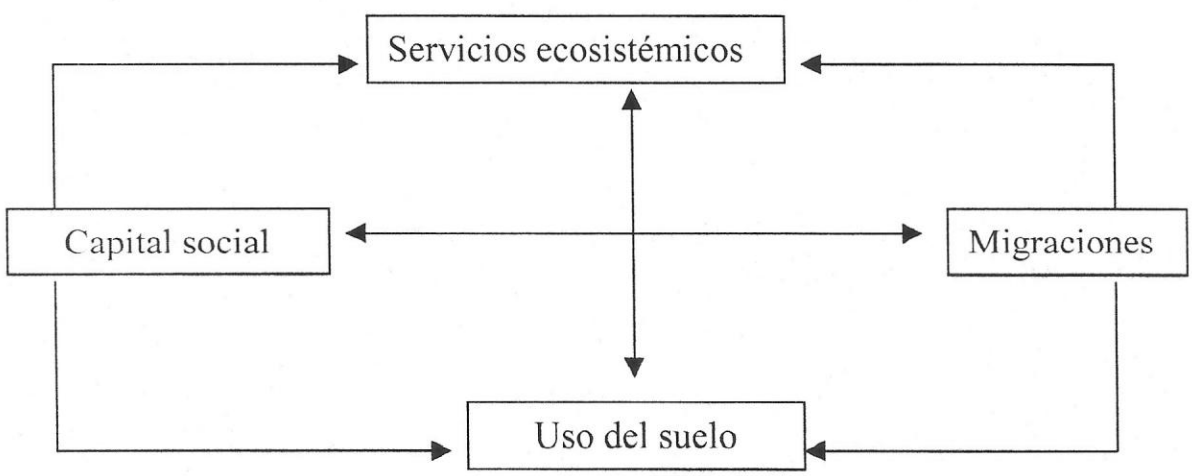
El capital social, como las otras formas de capital, es productivo y hace posible alcanzar ciertos objetivos que en su ausencia no serían posibles (Coleman 1990). Existe evidencia del efecto positivo del capital social en acciones de desarrollo (e.g. Grootaert y van Bastelaer 2002, Isham et al. 2002), y en acciones relacionadas con temas ambientales tales como manejo de cuencas, irrigaciones y manejo participativo de bosques (e.g. Katz 2000, Pretty y Ward 2001). Así mismo, el capital social puede resultar de gran importancia en los procesos migratorios debido a la existencia de redes de interacción social, las cuales disminuyen los costos y los riesgos asociados a la emigración (e.g. Palloni et al. 2001).

Luego de los años de violencia en Ayacucho, las políticas del gobierno peruano están enfocadas en la lucha contra la pobreza, la reconstrucción y el repoblamiento, mayormente basadas en la distribución de alimentos, creación de infraestructura y apoyo a la educación y la salud (PROMUDEH 1997). Muchas organizaciones no gubernamentales e instituciones del gobierno están promoviendo actividades productivas en las comunidades, incluyendo la habilitación de los tunales naturales. Esta habilitación incluye la apertura de caminos de acceso y remoción de la cobertura vegetal mediante la poda de arbustos, el desmalezamiento y la limpieza del terreno para facilitar tanto la colecta de cochinilla como la obtención de leña.

Diversas variables socio-económicas y demográficas (e.g. precios y salarios, migraciones, tamaño del grupo familiar) así como factores espaciales e institucionales (e.g. acceso a las zonas involucradas, conflictos violentos, derechos de propiedad) han sido identificados entre las causas de los procesos de remoción de la cobertura vegetal y cambio en el uso del suelo (cf. Barbier y Burgess 2001). Sin embargo el efecto del capital social sobre dichos procesos no ha sido evaluado.

Considerando la importancia de los servicios ecositemicos y el uso del suelo en el bienestar humano, los elevados niveles de migración temporal en Ayacucho, donde los campesinos emigran fuera de la comunidad por algunos meses luego de los períodos de cosecha o durante etapas del manejo de los cultivos en los que cuenten con excedente de mano de obra (INEI 1996), y que en Ayacucho existe evidencia que el nivel de organización comunal existente es alto (CTAR 2001), se plantea en este trabajo relacionar esos cuatro componentes: capital social, migraciones, servicios ecosistémicos y uso del suelo, sobre la base de las relaciones establecidas en el modelo conceptual general presentado en la figura 2, teniendo especial énfasis en relacionar la valoración de los servicios ecosistémicos con los procesos migratorios humanos y el cambio en el uso del suelo con el nivel de capital social. Existe una relación clara entre los usos del suelo y la provisión de servicios ecosistémicos asociados a cada uno de ellos, sin embargo muchos de los cambios en la provisión de dichos servicios son evidenciables a mediano o largo plazo, por lo que su cuantificación se encuentran fuera de la ventana temporal evaluada en este estudio y esa relación no es considerada en el estudio.

Figura 2. Modelo conceptual general



II) HIPÓTESIS

1 Si la migración temporal incrementa la resilencia social, diversificando los estilos de vida de los campesinos y promoviendo la inversión en recursos y activos, entonces los campesinos migrantes no diferiran en el conocimiento de los bienes y servicios brindados por los tunales pero los valorarán en mayor medida.

2 Si el capital social de los pobladores influye sobre las actividades productivas y el cambio en el uso del suelo, entonces los hogares con niveles más altos de capital social habilitarán los tunales más pronto y obtendrán más ingresos económicos que aquellos hogares con niveles de capital social más bajos.

III) OBJETIVOS

El objetivo principal de este trabajo es establecer las relaciones entre capital social, migraciones, servicios ecosistémicos y uso del suelo, en comunidades de Ayacucho en los Andes Peruanos.. Especialmente focalizados en relacionar la valoración de los servicios ecosistémicos con los procesos migratorios y el cambio en el uso del suelo con el nivel de capital social.

Para ello se plantean los siguientes objetivos específicos:

1 Identificar los bienes y servicios brindados por el ecosistema que son reconocidos por los usuarios.

2 Evaluar el nivel de capital social de los pobladores.

3 Relacionar la historia de migración temporal con el conocimiento y valoración de los servicios ecosistémicos.

4 Estimar el valor económico para las poblaciones locales, de los bienes y servicios provistos por los tunales reconocidos por los usuarios.

5 Estimar el efecto del capital social sobre los ingresos económicos de los campesinos.

IV) RESULTADOS

La tesis pone a prueba las hipótesis y desarrolla los objetivos propuestos, definiendo tres temáticas principales: *i*) el efecto de la migración sobre la identificación y valoración de los servicios ecosistémicos provistos por los tunales, ii) la vinculación de las normas sociales con el cambio en el uso del suelo, mediante la investigación del papel del capital social en la habilitación de tunales para la producción de cochinilla, y iii) el desarrollo de un modelo acoplado del sistema ecológico y económico referente a los tunales silvestres de Ayacucho.

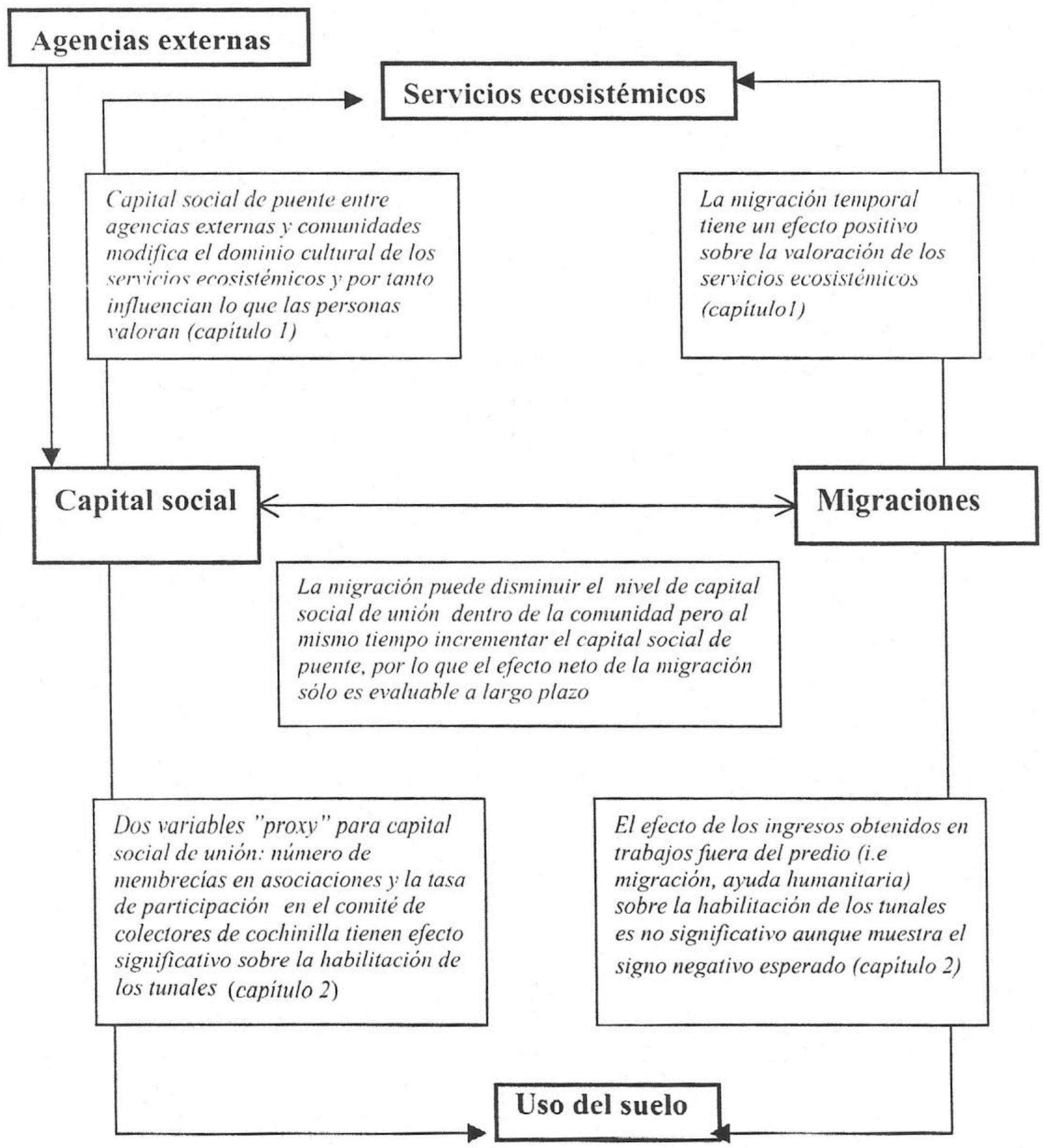
En el capítulo 1 " Local identification and valuation of ecosystem goods and services from *Opuntia* Scrublands of Ayacucho, Peru." se identifican los bienes y servicios provistos por los tunales reconocidos por los campesinos de Ayacucho mediante la exploración del dominio cultural de la *Opuntia*, luego se clasifica dichos bienes y servicios de acuerdo al tipo de función ecosistémica involucrada en su provisión, y posteriormente se evalúa el efecto de la migración temporal de los campesinos sobre la valoración de los servicios ecosistémicos, cuantificando en términos monetarios algunos de los bienes y servicios provistos por los tunales mediante diversas metodologías, i.e. precios de mercado, bienes sustitutos, costos evitados o valoración contingente, de acuerdo a su nivel de integración al mercado y a las estructuras y procesos involucrados en su provisión. Luego se cuantifica la contribución de los bienes y servicios provistos por los tunales en el ingreso anual de los hogares y se compara con sus ingresos provenientes de la agricultura. Finalmente, se hace un estudio comparativo del valor que tienen los tunales naturales de Ayacucho para las poblaciones locales, en relación con los valores de otros sistemas naturales obtenidos en distintos estudios en otros lugares del mundo. Los resultados de esta tesis hacen evidente que "lo que las personas valoran", referido a los servicios ecosistémicos, es un constructo dinámico y tiene una estructura interna posible de ser modificada por la acción de terceros (e.g. como consecuencia de labores de extensión derivadas del nivel de capital social *de puente* entre agencias externas y comunidades). Contrariamente a lo esperado, la migración temporal tiene un efecto positivo sobre la valoración del servicio de control de erosión provisto por los tunales. Este valor es aparentemente bajo debido a que muchos de los efectos negativos derivados de la erosión ocurren con un desfase espacial y temporal considerable y por tanto no son valorados por los usuarios locales. El valor de los productos no maderables obtenidos de los tunales por las poblaciones locales, en términos de participación en el ingreso del hogar es comparable con la agricultura, y en términos monetarios es similar al de otros sistemas naturales considerados *a priori* más valiosos, tales como las selvas húmedas tropicales.

En el capítulo 2, "Social Capital and Opuntia scrubland habilitation in Ayacucho Peru", se desarrolla brevemente la importancia de los tunales para las poblaciones locales de Ayacucho, y las políticas de lucha contra la pobreza que promueven la habilitación de tunales naturales para la producción de cochinilla, y se establece un paralelo con otras actividades humanas que generan alteraciones en la cantidad y calidad de la cobertura vegetal en los ecosistemas. Posteriormente, se revisan los factores identificados como importantes en otros estudios relacionados con procesos de deforestación y cambio en el uso del suelo, y se postula investigar el papel del capital social en dichos procesos, dado que no había sido considerado con anterioridad en ningún otro estudio. A continuación, se desarrollan algunos tópicos referentes al capital social relevantes para el estudio en cuestión y para las comunidades andinas, dado que el concepto de capital social es muy amplio y difícil de evaluar por si mismo, se definieron algunas variables sucedáneas para hacerlo operativo. Finalmente, dado que el número de hectáreas habilitadas es una variable censurada en cero, una estimación mediante mínimos cuadrados ordinarios, produciría estimados inconsistentes, por lo que se estima un modelo Tobit considerando el área de tunales habilitada como variable dependiente, y se identifican algunas de las variables sucedáneas de capital social *de unión* como variables significativas, las cuales son discutidas en el contexto de los canales por los cuales el capital social favorece la habilitación de los tunales, y la importancia del capital social en el establecimiento de lazos entre las comunidades locales e instituciones externas que promueven acciones de desarrollo. Los resultados sugieren que el capital social es un factor importante para explicar la habilitación de tunales. Algunas variables proxy para capital social, tales como la tasa de participación en las reuniones del comité de productores de cochinilla y la membresía en asociaciones, positiva y significativamente afectan la habilitación de los tunales. El efecto del capital social *de puente* establecido entre las instituciones comunales y organizaciones externas, podría ser importante en la intensificación de la recolección de cochinilla y en añadirle valor agregado al extraer y transformar los colorantes de la cochinilla.

En el capítulo 3, " Social capital, land use change and peasants' income: a model of *Opuntia* scrublands in Ayacucho-Peru" se desarrolla un modelo para la comprensión de la dinámica de los sistemas ecológicos y económicos en el área Andina, enfocado en el análisis de las relaciones entre una cobertura vegetal, en este caso los tunales naturales de Ayacucho, y algunos usos del suelo tales como recolección de cochinilla, cosecha de fruta y cría de ganado, resaltando el papel del capital social en el cambio en el uso del suelo mediante la habilitación de los tunales y su efecto sobre los beneficios obtenidos por los campesinos. El modelo es calibrado utilizando datos obtenidos en el trabajo de campo realizado en la provincia de Huamanga, complementados con información disponible en la literatura, y es utilizado para realizar simulaciones en un horizonte temporal de cinco años. Los resultados del análisis de sensibilidad permiten identificar algunos factores que podrían ser potencialmente importantes para el desarrollo de programas o políticas destinadas a elevar el nivel de vida en las comunidades de Ayacucho, e.g. el incrementar la calidad y no la cantidad del ganado, el efecto sobre los ingresos de los campesinos del incremento en la densidad de insectos y el esfuerzo de colecta de cochinilla, y particularmente el efecto significativo sobre los ingresos de los campesinos de mejoras en el proceso de comercialización de la cochinilla, disminuyendo el margen de beneficio de los intermediarios.

La figura 3 muestra el modelo conceptual general, modificado con la inclusión de las agencias externas, el cual es desarrollado en el capítulo 3, sobre la base de los resultados presentados en los capítulos 1 y 2. Así, el capital social de puente entre agencias externas y comunidades modifica el dominio cultural de los servicios ecosistémicos y por tanto afecta lo que las personas valoran. La migración temporal tiene un efecto positivo sobre la valoración de los servicios ecosistémicos. Algunas variables de capital social de unión tienen efecto positivo sobre la habilitación de los tunales. Finalmente, el efecto de los ingresos obtenidos fuera del predio no es significativo sobre la habilitación de los tunales en Ayacucho.

Figura 3 Modelo conceptual general y resumen de resultados.



Capítulo 1

Identificación y valoración local, de los bienes y servicios provistos por los tunales silvestres de Ayacucho, Perú. [Local identification and valuation of ecosystem goods and services from Opuntia Scrublands of Ayacucho, Peru]

Local identification and valuation of ecosystem goods and services from Opuntia Scrublands of Ayacucho, Peru.

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ABSTRACT

Opuntia scrublands are important ecological-economic systems in the Andean area. They perform a major role protecting slopes against erosion, improving the soil properties, and providing a variety of products employed in the human diet and in animal feeding, as well as cochineal insects, a highly valued source of dyes. The collection of cochineal insects has represented an important economic activity for local communities in the Andean area and Mesoamerica since pre-Columbian times. Current Peruvian production represents between 85 and 90% of the global market, and is mainly based on recollection of the insect in natural Opuntia scrublands located in the poorest Andean areas of Ayacucho. Although much is know about the financial benefits of cochineal for exporters and dye manufacturers, information about the financial value of standing Opuntia scrubs to collectors and the relative contribution of Opuntia scrubs to their household economies is scarce. Here we contribute to the estatimation of the use value of Opuntia scrublands to local communities in Ayacucho by initially exploring the cultural domain of Opuntia in order to identify the ecosystem goods and services recognized by peasants, and later presenting empirical estimates of their importance to annual household income.

KEYWORDS: Cochineal, Opuntia, Peru, ecosystem services, valuation

1. Introduction

Ecosystem services is a concept that has gained much attention in diverse scientific circles in recent years, emphasizing their importance for human societies. Nevertheless, some ecosystem services may not be easily recognized and understood by the widespread public due to their abstract nature, the impossibility to be perceived with the senses, or the need of previous empirical knowledge or theoretical learning (Lewan and Söderqvuist 2002). Most ecosystem valuation research is too focused on the question "what is the value" and not enough on "what, in particular, people value" (Swallow et al. 1998). The latter requires to find out how people actually recognize or use the current and future benefits provided by Nature. One such example, that has received little attention, is provided by Opuntia scrublands, one of the most important Andean socio-ecosystems in terms of the social and ecological functions they provide.

Opuntia scrublands perform a major environmental role protecting slopes against erosion and flooding, as well as rehabilitating marginal lands by improving the levels of humidity and soil retention capabilities. Opuntia scrubs are also used for animal grazing all year round and can become an emergency feedstock in case of drought. In addition, its fruit and young cladodes have a considerable nutritional value and provide food for Andean peasants. In fact, the fruit can be eaten fresh or used for the preparation of syrup, as well as fermented and non-fermented beverages. Opuntia plants have a broad range of other uses, from living fences for protecting crops to organic material for composting and building material for adobe making. The plant mucilage flocculates turbid water and is a good adherent for wall painting, while the wood is used to some extent in the manufacture of ornamental and rustic work such as picture frames or lamps (Le Houérou 1996)

Opuntia scrubs are especially important because they host cochineal insects. These insects are the source of carminic acid, a natural dye used in the food, textile, and pharmaceutical industries. The collection of the insect has represented an important economic activity for local communities in the Andean area and Mesoamerica since pre-Columbian times. Current Peruvian production represents between 85 and 90% of the global market, and is mainly based on recollection of the insect in natural Opuntia scrublands located in the Andean area of Ayacucho (Flores-Flores and Tekelenburg 1995). Due to the favorable environment for both the insect and its host plant, cochineal collection in Peru has a considerable social and economic importance, representing a source of income for some 100,000 peasant families. These families inhabit poor communities exposed to social vulnerability, disruption of livelihoods, and loss of security as a consequence of 12 years of violence derived from the actions of groups such as Shining Path, and armed peasant patrols, and of the Peruvian army (Fumerton 2001).

Although we know much about the financial benefits of cochineal exports and dye manufactures (PRA 2002), we know much less about the financial value of standing Opuntia scrubs to local users and the relative contribution of the Opuntia scrubs to household consumption and to household income. Without that assessment, it is not possible to evaluate alternative uses of the land or determine whether there are sufficient benefits from Opuntia scrubs to provide incentives for local communities to participate in their protection and sustainable management.

Here we contribute to the estimation of the use value of Opuntia scrublands to local communities in Ayacucho by initially exploring the cultural domain of Opuntia in order to identify the ecosystem goods and services recognized by them. Then, we present empirical estimates of their importance to annual household income, valuing some of these goods and services as well as others not elicited in the cultural domain, but effectively used by local populations.

The remainder of the paper is organized as follows. In the next section a background to the case study area is offered. Section 3 describes the cultural domain analysis. Then Section 4 describes the method used to derive the values of the different uses and offers an estimate of the economic value of the scrubland. Lastly, the paper offers a discussion of the main results, and conclusions.

2. Background

The Huamanga province was selected for the study because it is one of the most important areas of cochineal collection in Ayacucho. Six villages sharing similar agroecological and socio-economic conditions were included in the study: Violeta Velásquez, Tambobamba, Condoray, Paraíso, Compañía, and San Juan de Yucaes. These villages are located in an area ca. 2500 meters of altitude with mean monthly temperatures ranging from 11 to 24 °C and yearly average rainfall of 754 mm distributed from October to March. The vegetation cover consists of a variety of grasses of the genera *Bouteloua, Heteropogon, Pappophorum* and *Aristida*. Isolated specimens of *Schinus molle* (Anacardiaceae), *Caesalpina tinctoria* (Caesalpinaceae), *Agave americana (*Agaveaceae*)* and cacti of the genera *Cleistocerus* and *Azureocereus* contrast with the abundance of Opuntias, which become predominant as the slope increases and reach stand densities over 2000 plants/ha (Piña-Lujan 1981).

Similarly to other communities along the Andes, nuclear households are predominant, with about five members living at home and often more than one member migrating outside the community. Quechua is the native language of the inhabitants of the villages. Although most of them are fluent in Spanish, all conversations among themselves occur in their mother language. Farmers in the Andes do not constitute an homogenous social group. Processes of internal differentiation occur within villages as a consequence of uneven distribution of local resources and on different articulations within the larger economy (Bianco and Sachs 1998).

The rural economy is highly diversified although agriculture is the main activity. While land is communally owned and communally farmed on an obligatory basis, individual household plots abound for production purposes using family labor and reciprocity relationships in the communal network. Household land plots are fragmented and holdings undergo constant division because of demographic pressure and inheritance practices. Hence, land tenure follows a process of accumulation and release along the individual life cycle, a pattern shared with most communities in Ayacucho (Ossio 1992). Because of shortage of pastureland there is a limited opportunity to raise cattle. In fact, ownership of livestock is suggested as one of the principal basis of differentiation among families in the Andean communities (Montoya 1982). However, this is not necessarily correlated with land tenure due to the use of crop byproducts such as corn stalks for animal husbandry as well as weeds and vegetation growing in Opuntia scrublands (Gade 1999). These animals are rarely consumed; instead they are kept as capital asset that can be liquidized when the need arises.

In an ecological context characterized by limited space available for agriculture, steep slopes, marginal soil fertility, and seasonal weather, Andean people have developed a rather complex farming system to meet their subsistence needs. Andean peasant communities usually practice an agro-pastoralism that takes advantage of environmental diversity in order to minimize risk. That behavior is reflected in the existence of a great variety of crops for subsistence, and a cash crop or cattle raising for the market (Valdivia 1996). The Andean idiosyncrasy is also evident in community levels of social organization, long-standing patterns of mobility, reciprocity of obligation, and duality of spatial organization. Land uses typically overlap. Cochineal is harvested in Ayacucho from Opuntia scrublands, locally known as *tunales,* thus making productive use of communal lands and supplementing peasant's livelihood (Gade 1999).

3. Local identification and valuation of ecosystem goods and services

The general framework:

For tractability, the economic valuation of Opuntia scrublands requires to translate the ecological complexity of structures and processes into a short number of ecosystem functions, which in turn provide environmental goods and services. The types of ecosystem functions resulting from natural processes in Opuntia scrubland can be characterized, following de Groot et al. (2002), in: (i) production function, (ii) habitat function, (iii) regulation function, and (iv) information function. An overview of the functions relevant to Opuntia scrublands grouped in the four mentioned categories, as well as the ecological structure and processes occurring in that system and some of the goods and services provided is presented in Table 1.

Semi-structured surveys were used in the field to gather information from 126 households in 2002. This information was both qualitative and quantitative. The selection of the surveyed households responded to simple random sampling requirements under a voluntary participation scheme. Among the quantitative information, data were obtained about the frequency and quantity of collections of different goods from the scrubland on an annual basis as well as the labor input used in collecting these goods. In addition, with the aim to explore the participation of Opuntia scrublands in the structure of households' income, information concerning agricultural outputs, cattle raising, remittances, and other productive activities was also collected.

Because not all ecological services provided by Nature are well known or apparent, they are sometimes ignored by external agencies, in many instances they are not properly assessed when analyzing local users' land conservation incentives. For this reason, we initially explored the cultural domain of the goods and services provided by Opuntia scrublands. A total of 26 voluntary stakeholders were involved in this investigation. In contrast with standard valuation, which represents choices or preferences, the cultural domain is an organized collection of items which represents perceptions, and provides a complementary point of view to the understanding of internal relationships among the goods and services and between the ecosystem and the social systems.

Local identification of goods and services provided by Opuntia scrubland

In spite of the anthropocentric importance of ecosystem services with regard to social well-being, not enough is known about their recognition by local users themselves (Kaplowitz 2000, Lewan and Söderqvist 2002). Social sciences have developed a set of qualitative methods, which constitute comprehensive tools for that assessment. Cultural domain analysis provides a set of techniques to investigate the structure of knowledge. Following Borgatti (1998) the freelisting and triads techniques were applied to elicit the elements of the cultural domain and the attributes that local households use to distinguish among the items. Through semi-structured interviews, a list of uses and benefits provided by Opuntia scrubland were identified (table 2). Then, in order to elicit from the respondents judgements of similarity among these items in the cultural domain, 30 triads were created. This was done by employing a balanced incomplete block design with lambda 2, using the ten most frequent elements obtained in the freelist, i.e. the core of the domain. The triad results were transformed in a similarity matrix and submitted to cluster analysis (Figure 1) and to multidimensional scaling (Figure 2) in order to generate a two-dimensional representation of the relationships between the core elements of the cultural domain of Opuntia.

Valuation of ecosystem goods and services provided by Opuntia scrubland:

As explained above, the ecological goods and services provided by Opuntia scrublands are very diverse in the structures and functions involved in their supply, in their level of integration to the markets, and in to their contribution to peasant well-being. Some of goods and services supplied by Opuntia scrublands are not considered in the cultural domain since they provide global benefits which local populations are not aware of e.g. regulation of atmospheric gases by CO_2 sequestration. Other goods and services effectively included in the cultural domain represent the outcome of extension activities rather than local use e.g. the cooking of young cladodes. On the other hand, there are some goods and services used by local populations which were not elicited in the cultural domain of Opuntia due to their abstract nature or the incapability of respondents to dissociate them from natural cycles e.g. the refugium service. Since we aim to assess the use value of Opuntia scrublands, this study covers the ecosystem goods and services effectively used by local population in Ayacucho, elicited in the cultural domain appraisal, or identified in the fieldwork.

In this section we briefly describe the approach used to value these goods and services, as well as the results expressed in monetary terms. Firstly the direct use value of Opuntias in terms of their production of food, fruit, cochineal, fodder, fuel and ornamental goods is estimated using direct market prices and when required, the value of the closest substitute goods. Then, an attempt is made to assess the habitat function value through its nursery and refugium services, based on an avoided cost approach, and lastly an estimate of the indirect use value regarding the regulation function of the on-farm erosion control service is provided through a contingent valuation. Due to limited data and the complexity of natural systems, we were able to estimate only partially the value of some key goods and services (see Boumans 2002).

Value of production function

Peasants are regularly visited by traders involved in the commerce of cochineal. These traders buy cochineal and develop arrangements for future transactions in order to accumulate cochineal stocks and dispatch them to more wealthy traders who later transport and sell the larger amount of insects demanded by export companies. The supply of fruit largely exceeds the local demand of the product and since its quality does not always fit well the requirements of markets, most fruit is not harvested.

After quantifying the yearly harvest of scrubland products, such as cochineal and fruit, and controlling for product quality (i.e., first or second quality fruit, dry or fresh cochineal) and the area used in the collection, market prices were used to derive the use value of the products collected in a given year. These prices were obtained from a representative selection of stakeholders and traders in order to be employed in the valuation approach.

Peasants usually buy young cattle and sell it after a year of stocking. Although Opuntia plants can be used as fodder by harvesting cladodes and including them in the diet, plants are more often directly browsed by livestock. The share of Opuntia browsed by cattle depends on herd size and season (Guevara et al. 1996a, 1996b). To properly evaluate cattle diet composition through the year, field observations and reports from peasants have been used. The value of Opuntia scrublands as provider of feedstock is calculated by multiplying the yearly livestock profits by the percentage of Opuntias (30%) of the total feedstock intake used in the diet of the cattle. This conservative percentage is concordant with empirical studies of browse consumption for low stocking rates in other Andean areas (Guevara 1996b).

Wood is the main energetic resource used by peasants for cooking, often collected by elderly people and children. The vegetation removed as a result of Opuntia scrubland habilitation is usually employed for firewood and normally collected by the head of the household. Besides family labor there is a market for hired labor under a salaried basis (Cotlear 1989). The value of Opuntia scrublands and the associated vegetation as sources of fuel was thus quantified considering the wage rate as a broad approximation of the opportunity cost of time employed by households in periodic labors such as taking out grasses and fallen branches after habilitating the scrublands that generate supplies of fuel.

Columnar cacti are occasionally collected and sold to artisans for the manufacture of handicrafts. The value of the vegetation as a source of ornamental resources is calculated based on the market value of the raw material and the area searched for specific items. This approach tends to overvalue the benefits of the activity because there is no guarantee that the demand for the collected cacti will match the supply at any given year, implying that not all the scrubland area is valued for this service. Assuming that the total demand for ornamental resources is supplied, a conservative assessment can be estimated (Table 3).

Value of Habitat Function

Cochineal is a sessile parasitic insect living on Opuntia plants. First instar nymphs are the only mobile life stage. These nymphs crawl and disperse along the host plant searching for a place to settle or are transported by the wind to other potential hosts, thus colonizing distant areas. Once settled, nymphs become sessile and develop to adult insects. Due to their lack of mobility, cochineal insects are easily collected by peasants using soft brushes or spoons to withdraw them from the plants. In most cases, only the less accessible insects or plants are left untouched. These cochineal insects, settled in so-called refugium areas, later re-colonize the scrubland. The value of the service of nursery and refugium is quantified based on the costs avoided by peasants if the host plants should be infested by hand, a common practice in commercial cochineal exploitations where adult females are artificially attached to uninfested plants in order to create new colonies and increase the density of the already existent colonies (Table 3).

Value of Regulation Function

As mentioned in the previous section, the regulation function of Opuntia scrubland can have an important indirect use value for local communities. Among the potential functions, the one corresponding to erosion control has been explored further as it appears important in the Andean context.

Opuntia scrublands are not interspersed among the crops. Any approach to measure the service of erosion control based on the change in fruit production and cochineal collection will be biased due to the extraordinary resistance of the plant to soil degradation. Hence, any change in productivity will be evident only after many years of severe soil loss. However, erosion remains a major problem in the Peruvian Andes. Over 80% of the land is eroded, and much of the erosion is typified as laminar and consequently is not evidenced immediately (Alfaro and Cardenas 1988). Differences in the perception of erosion and its impacts can be observed in diverse community sectors (Korshing et al. 2001). Peasants' interest in soil erosion is primarily concerned with on-farm impacts such as increased production costs, decreased profitability owing to soil fertility decline, and financial costs of implementing needed soil conservation measures. Cochineal collectors are in close contact to the markets, even in remote communities in Ayacucho. This high level of integration to the markets, led us to explore the possibility of developing a Contingent Valuation (CV) study with the aim to get a broad monetary idea of the households' willingness to pay (WTP) for the service of soil erosion control provided by the Opuntia scrubland.

A conservative single-bounded dichotomous choice WTP elicitation format was adopted, based on Hanemann's (1984) Random Utility Maximization (RUM) model.[1] Focal groups meetings were developed to define five bid options: 0.5, 0.75, 1, 1.5, and 2 *nuevos soles* (NS) per month/ha, equally divided amongst respondents. We tried to adapt the study to the local conditions and idiosyncrasy of the respondents so the payment vehicle selected was a contribution to communal funds, particularly in view of the lack of other realistic means of payment such as taxes or services bills, and because communal institutions have experience in collecting and managing funds.

A major stream of proposed discrete choice models to estimate WTP in CV is based on the probability of accepting the bid proposed to the respondents by applying a random utility model (RUM). The underlying assumption is of respondents' utility maximization wherein they accept the bid if the utility (or satisfaction) achieved under the scenario of lower soil erosion through conserving the Opuntia scrubland is higher than the cost (accepted WTP bid), or is greater than the utility without alteration (Habb and McConnell, 2002).

Under the RUM framework, the indirect utility function for each respondent can be expressed as a random variable (Park et al. 1991):

$$U(i, y; s) = V(i, y; s) + \varepsilon_i \qquad [1]$$

where y is household income, s is a vector of household socioeconomic characteristics, and *i* is the binary choice variable (1 if the respondent is willing to pay the bid amount, 0 otherwise); in addition ε_{ij} is the stochastic, and independently and identically distributed random error, an element interpreted as consisting of characteristics of the individual and attributes of the alternatives considered to influences on individuals' choice (Hanneman, 1984). It is assumed that when faced with a bid, b, for the proposed control of soil erosion, the respondent will accept the bid, i.e. $i=1$, if

$$v(1, y\text{-}b; s) + \varepsilon_1 > v(0, y; s) + \varepsilon_0 \qquad [2]$$

Hence, the probability of accepting the bid is given by:

$$\Pr[i=1] = \Pr[v(1, y\text{-}b; s) + \varepsilon_1 > v(0, y; s) + \varepsilon_0] = F_\varepsilon(\Delta v) \qquad [3]$$

[1] It has been suggested recently that the single- and double-bound CV models yield similarly efficient point estimates when the sample size is large and when the former is informed by a pre-test conducted on a small population (Calia and Strazzera, 2000).

where $F_\varepsilon(\Delta v)$ represents the cumulative density function of the respondent's WTP for the conservation of soil erosion retention services by the Opuntias. This is commonly modeled as a logistic function:

$$\Pr[i=1] = \frac{1}{[1 + \exp(\Delta v)]} \qquad [4]$$

which can be easily estimated using a binary logit model (Hanemann, 1984). Nevertheless, this RUM framework can exhibit some problems, and other models have been suggested for the efficient estimation of contingent valuation surveys. Cameron and James (1987) proposed a theoretically consistent alternative based on the known willingness to pay and the assumption that each individual is confronted with an arbitrarily chosen bid t.

$$WTP_i = X_i\beta + \varepsilon_i \qquad [5]$$

Where WTP is the willingness to pay. X is a vector of explanatory variables and ε_i is a random error independent and identically distributed with mean zero and standard deviation σ. For willingness to pay, we denote the acceptance of the bid by $y_i=1$, and a rejection by $y_i=0$. Then, assuming a normal distribution for ε_i and standardize, we can derive :

$$\Pr(y_i=1/X_i) = \Pr(WTP_i > t_i)$$

$$= \Pr(X_i\beta+\varepsilon_i > t_i)$$

$$= 1-\Phi((t_i - X'_i\beta)/\sigma)$$

where Φ denotes the standard normal cumulative density of the respondents WTP.

Since households' potential payment is expected to be small relative to their available income, it is not likely that the marginal utility of income varies with the income of a given respondent. One practical way to incorporate the effect of income, and at the same time allow the marginal utility of income to vary across individuals is to use income categories and to let the coefficients vary according to income category. This approach has the advantage of avoiding the effect of errors in the measurement of income, while at the same time capturing some of the differences among households due to income differences (Haab and Mc Connell, 2002).

Recalling [5], a linear model for the willingness to pay is represented as follows:

$$WTP_{ij} = \alpha_i z_j + \delta_1 w_1 y_j + \delta_2 w_2 y_j + \varepsilon_{ij} \qquad [6]$$

where y_j is household *j*'s discretionary income, z_j is the vector of variables related to household j, α_i is a vector of parameters, and ε_l is the unobservable error term. Letting the marginal utility of income to vary across individuals with different income levels such that $\beta=\boldsymbol{\delta w}j$, where $\mathbf{w}_j = \{1, \mathbf{w}_{1j},... \mathbf{w}_{Kj}\}$ is a vector of individual specific covariates associated to the parameter bid vector $\boldsymbol{t}$. In our case, **w**j represents a vector of variables indicating if income belongs to a specific income stratum. Hence, income y_j is classified as a categorical variable such that a household in each stratum has a different marginal utility of income. We define $w_{ij}=1$ if $y_j<c$; 0 otherwise, and $w_{2j}=1$ if $y_j>c$; 0 otherwise, where the threshold c represents the subjective extreme poverty line in the case study area.[2] Hence, the sample is divided into two subsamples according whether the household is above or below the poverty line.

[2] The subjective extreme poverty line is based on the perception of the minimum income level that the household considers necessary to live, and was estimated in 76.5 nuevos soles per month (Herrera 2002)

The variables in vector z are presented in Table 4 and include several socio-demographic household characteristics such as dependency relationships (labor force/family size ratio, and presence or absence of dependents within the household), as well as gender and age of the head of the household. The former are proxies for household labor capacity, while the age of the head of the household was included due to its relation with physical capital level and land tenure. A set of education related variables as proxies for human capital, were also considered in z. These included years of formal education and literacy since it is not uncommon that in spite of school attendance many persons are functional illiterates; the number of elicited elements of the Opuntia cultural domain as a proxy for traditional knowledge of the system, was also included. Finally, since the perceptions of community problems and actions toward their solution are mainly determined by peasant embeddinness and the perceived benefits and costs of the problem and solution, variables such as migration experience, the share of farming income, and erosion perception were included in the study.

The results of the multinomial Logit model to estimate the effects of the z and income variables on WTP are presented in Table 5.[3] The generalized likelihood ratio statistic, 91.99 distributed as Chi-squared with 12 degrees of freedom shows that the model explains the variability in the acceptance of bids satisfactorily. The mean WTP is given by:[4]

$$E(WTP) = -\frac{\delta}{\beta} \qquad [7]$$

[3] The Lagrange Multiplier test suggested that error term is not normally distributed and therefore a Multinomial Logit was used instead of a Probit model (Green, 1993).

where β is the value of the coefficient of the cost variable in the estimated logit equation, and δ is the sum of all other terms in the equation evaluated at the mean values of the explanatory variables. The analysis reveals a mean monthly WTP of 1.33 NS per hectare (15.96 NS per year). This is a relatively low value partly on account of households' low incomes and also because the identification of physical damage due to soil loss is complicated by spatial and temporal discontinuities. The low WTP may be understood since farmers have little incentive to control off-farm costs of soil erosion (Crosson 1986). However, the estimated yearly WTP for the service of erosion control from the Opuntia scrublands correspond to ca. 3% of the value of cochineal collected. In spite of the differences in inputs and activities, this result is in the same order of magnitude of the environmental damages from agriculture in most regions of the United States (Smith 1992).

The model indicates that the likelihood for peasants agreeing to pay the proposed amount decreases as the bid increases. In addition, as expected, the likelihood of accepting the bid significantly increases if the respondent effectively perceives soil erosion or obtains a high proportion of his income from the farm. Additionally, households with no dependants are more likely to reject the proposed bid. Due to the cyclic phenomenon of land accumulation and release that characterizes land tenure system dynamics in Ayacucho (Ossio 1992), households without dependents mainly correspond to either young or mature couples, and in both cases these households possess smaller land extensions, their income levels are lower, and consequently the likelihood to accept the bid decreases.

[4] From a theoretical viewpoint, the mean WTP is often preferred over median WTP as a measure of welfare (Johansson et al. 1989).

The likelihood of accepting the bid increases significantly as the ratio labor force/household size increases. This could be due to the fact that households with lower dependency ratios normally have a higher per capita income, allowing them to reallocate resources out of the family subsistence sphere towards investment in human or physical capital to enhance household production and reduce social vulnerability (Bianco and Sachs 1998, Locke et al. 2000).

The effects of migration on environment are undetermined and, as Curran and Agardy (2002) and Noronha et al. (2002) argue, selective migration can change social relationships and the value of ecosystem services to the local population and consequently modify ecosystem management. In this study, the coefficient related to migration experience exhibits a positive and statistically significant sign. This seems unexpected at first sight since it may be supposed that migrant peasants might be involved in a dissembedding process from Nature, and consequently they might be less concerned about the level of damage to natural systems (Giddens 1991, Borgström y Wackernagel 1999). However, in Ayacucho, temporal migration as well as the cyclic process of land tenure and the endogamy characteristic of the mechanisms of land accumulation and release do not facilitate the dissembedding process. Contrarily, this type of migration and the fact that in these communities, land is scarce (i.e. IER 1985, Perez Liu 1988) are incentives to promote investment in physical capital (Locke et al. 2000, Adger et al. 2002).

Labor shortage is considered a cause of the inadequate attention to agriculture and environmental degradation, and also of the negative effects on cultural and social organization in emigration areas (Zimmerer 1993). However, in these communities, similarly to other places in the Peruvian Andes (e.g. Gonzales de Olarte 1984), emigration processes only take place after labor force is sold within the community; hence, the labor shortage reasoning for environmental degradation is weak. The arguments exposed in relation to the kind of migration, land scarcity and lack of labor shortage may explain the disposition of migrant peasants to accept the bid.

4. Discussion

Regarding the identification of goods and services provided by Opuntia scrublands, the cultural domain appraisal provided us with a departure point to understand the local perception of the internal relationships among these goods and services, as well as the relationships between the scrubland and other social and economic systems.

The multidimensional scaling and the complementary cluster analysis show two clusters conformed by i) marmalade, salad, and fruit; ii) cattle, fences, fertilizer, soil, food and chicha; and an isolated element, cochineal. The first cluster shows the direct relationship between the fruit and its processed products. The second one is related to croplands and subsistence. The existence of an isolated element and the associations inside the second cluster may be explained on the basis of the recurrent Andean strategy of crop production mainly for subsistence, while simultaneously having another activity as source of cash such as cattle raising or, in Ayacucho, cochineal collection (Gade 1999). Thus, the second cluster includes a series of food security, where cattle manure and Opuntia compost supply organic fertilizer to the soils to increase crop production, while fences provide crop protection by reducing the loss of crops from animal grazing. Furthermore, livestock supplies animal force, which can be used in the family cropland or interchanged with human labor for certain tasks, thus maintaining the relations of cooperation and reciprocity in the community (Cotlear 1989). These goods and services link the elements of the cultural domain of the Opuntia to the agropastoral system, to risk reduction, and to coping strategies such as soil improvements and crop protection that are usually concerned with maintaining the assets and the capacity of the household to generate future-income and avoid social vulnerability (Watts and Bohle 1993). The Andean organization considers a set of different production cycles in the community in order to promote the intensive use of available labor force (Valdivia 1996). Cochineal collection occurs as an isolated element very distant and unrelated to the other elements of the cultural domain, because the insect is not consumed and it is not part of the production cycle for food security. Cochineal is a source of cash and the key element in the socio-ecosystem because it permanently links the natural system represented by Opuntia scrubland to the economic system evidenced by markets. The simultaneous existence of both subsistence crops and a product for the market has been considered a cause of differences in the access to resources, of modifications in the labor relations, and finally of changes in the social organization of Andean communities (Golte 1980). Following the notion of embeddedness (*cf.* McCay and Jentoft 1998), from which the Man's economy and any productive activity is enmeshed in social relationships, and the fact that the social and ecological systems are indeed connected (Berkes and Folke 1998), this analysis adds social and community dimensions into the framework of the cultural domain of Opuntia in Ayacucho, and makes evident the linkage between the scrubland and both the agropastoral and the socioeconomic systems involved in peasants livelihood.

Some of the elements of the cultural domain of Opuntia elicited by respondents may represent a result of the extension activities of NGO's but do not necessarily imply application of the provided knowledge. For example, generic terms such as food and chicha, appeared in the domain, although peasants in Ayacucho do not regularly prepare meals with Opuntia neither ferment fruit for drinking chicha. The appearance of these elements is no doubt an outcome of tasting sessions and exhibitions organized by NGOs to promote Opuntia and cochineal. On the other hand, other uses and benefits of Opuntia previously reported by peasants, such as diabetes control, veterinary treatments or flocculation of turbid waters were not elicited, and some reported uses exhibited a lower frequency than expected, based on the certainty that they were recognized since pre-Columbian times, such as adobe making and paint manufacture (Pardo 2002). These findings clearly show that "what people value" referred to ecosystem services is a dynamic construct defined by the users, and has an internal structure susceptible to modifications, as are all elements of a cultural domain. Nature is not a pre-given thing, which everyone experiences in a similar way; it is always experienced as a localized phenomenon, and considered under particular and local frames of references. Nature is experienced by senses and through the senses new ways of apprehending Nature and the natural have been socially organized (Franklin 2002). In this regard, the level of embodiment between Nature and society is an important concept for the recognition of the goods and services provided by natural systems. Ecosystem services is not an environmental issue imposed upon societies; rather it is in some way socially constructed based on ecosystem processes and components which may affect human well-being and, similarly to other environment related issues (Irwing 2001), the kind of evidence and expertise upon which people draw when seeking to interpret and understand Nature, may explain the great differences in how social groups select which set of ecosystem services to be concerned about.

It is undeniable that social groups are more concerned about those goods and services which have use value. Among them, non-timber forest products (NTFPs) have come to play an important role in large-scale commercial income generation and employment in many parts of the world due to increased market demand (Sinha and Bawa 2002).

In monetary terms, Godoy et al. (1993) in a review of about two dozen studies of the value of non-timber forest goods suggest a median annual value of about US$ 50/hectare/year. In a worldwide review of the value of food and raw material collected from rainforests, Costanza et al. (1997) found average annual values of US$ 32/hectare and US$ 315 /hectare, respectively. Nevertheless, in a panel data study in Bolivia and Honduras, the value of the goods collected from the forest was under US$10/hectare/year (Godoy 2002). This value is below the lower end of the previous estimates, but in the same order of magnitude of the findings of Soren (2001) and Kvist et al. (2001) who report values of about US$15/hectare/year for the local extraction of NTFPs from Peruvian Amazon, and certainly a small fraction of the US$5702-11265/hectare/year obtained from commercial extraction of NTFPs in areas where high value palm is the dominant species (Muñiz-Miret et al. 1996).

On a comparative basis, the total value of the NTFPs collected from Opuntia scrublands considered in the study represents over US$400/hectare/year, a value in the range of magnitude of other natural systems such as tropical rainforest. This result underlines the view that generally the attention paid to tropical forest systems such as Amazon lowlands has been disproportionately high compared to the Andes (Henderson et al. 1991, Mares 1992, Young 1997).

The importance of NTFPs to local economies is more evident in their contribution to household income. Some studies suggest that their sustainable harvest could be higher than timber income or income from agriculture (e.g. Peters et al. 1989). Some rural communities obtain about 40-63 % of their income from collection of NTFP and in some cases the collection of a single specific product could represent as much as 40% of their income (Runk, 1998). In Ayacucho, where some communities obtain about 10% of their income from external aid agencies, the items collected from Opuntia scrubland represent as much as 36% of their total income, very close to the income obtained from agriculture (Figure 3) and in line with the report of Escobal (2001) for the off-farm income levels in rural Peru.

Even if only some of the intangible benefits are considered, the value of the ecosystem services is relatively higher than the computable direct financial revenues from agriculture (Figure 4). This points towards the need to conserve the flow of values provided by Opuntia as is a fundamental asset for Andean peasants. This is even more relevant especially since market prices rarely reflect the positive externalities generated by this ecosystem, and since if only left to the realm of market forces, this may lead to short-term over-exploitation of the scrubland, hence reducing local users welfare levels.

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TABLES AND FIGURES

Table 1. Functions, goods and services of Opuntia scrublands*

Functions	Ecosystem Processes and Components Involved	Goods and Services References
Production Functions	*Provision of natural resources*	
Food	Conversion of solar energy into edible plants and animals	Fruit and young cladodes for human consumption (Pimienta Barrios 1994) Fodder for cattle (Guevara 1996) Traditional fermented and non-fermented beverages, syrups, and conserves (Vigueras and Portillo 2001)
Raw materials	Conversion of solar energy into biomass diverse uses	Fuelwood source (Pardo 2002) Cladodes employed for biogas obtention (Contreras and Toha 1984) Claododes used for obtain organic fertilizer by composting process (García de Cortázar et al. 2001) Building material (adobe making) (Pardo 2002)
Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for handicraft, lamps decoration (Yasseen et al. 1996) Fruit are used as dye sources (Vigueras and Portillo 2001) Opuntia mucilage is used as base for traditional paint mixed with colored powders (Pardo 2002)
Habitat Functions	*Providing habitat (suitable living space) for wild plant and animal species*	
Refugium function	Opuntia scrublands cladodes provide breeding and nursery areas to cochineal insects that later are collected for commercial purposes	Maintenance of cochineal stock. Avoids the cost of manual infestation of Opuntia plants (Flores-Flores and Teckelenburg 1995)
Regulation Functions	*Maintenance of essential ecological processes and life support systems*	
Disturbance prevention	Opuntia scrubland biomass prevent drastic famine events	Prevention of drought effects (Nefzoui and Ben Salem 2001)
Water regulation	The vegetation cover provided by Opuntia scrubland regulates runoff	Runoff regulation (Le Houérou 1996)
Water supply	Opuntia increases the capability of soils to retain and store water	Increase rain use efficiency (Le Houérou 1996)
Soil retention	Role of vegetation root matrix and soil biota in soil retention	Land rehabilitation, prevention of damage from erosion (Le Heouérou 1996)
Nutrient regulation	Opuntia scrubland increases the organic matter (40%) and nitrogen content (200%) of the soils compared with open field	Maintenance of soil fertility (Monjauze and Le Houérou, 1965)
Information Functions	*Providing opportunities for cognitive development*	
Cultural & artistic information	Variety of natural features with cultural and artistic value	Many lyrics of Pumpin music, a traditional genre in Ayacucho are inspired by the Opuntia. Lyrics represent advices, rules and norms for the sustainable use of the goods and services provided by Opuntia scrublands (Fieldwork 2002, Comunidad de Quilla).

* Adapted from de Groot et al, (2002).

Table 2: Elements of the cultural domain of Opuntia scrublands.

Elements of the cultural domain of Opuntia	**Occurance (n° of households)**	**% (of total)**
Cochineal	126	100
Fruit	126	100
Cattle	126	100
Fences [a]	104	82.5
Food [b]	45	35.7
Chicha[c]	44	34.9
Fertilizer [d]	39	30.9
Marmalade	24	19.0
Salad [e]	16	12.6
Soil [f]	14	11.1
Wine[c]	13	10.3
Land [f]	8	6.34
Adobe	4	3.17
Erosion	2	1.58
Paint	1	0.79
Fumigate [g]	1	0.79

a The term refers to living fences made with Opuntia plants.

b This generic term refers to cooked meals.

c Chicha and wine are fermented beverages obtained from Opuntia fruit. They differ in preparation and alcoholic content.

d Opuntia cladodes are a source of biomass for composting. Although this element was elicited, it does not correspond to a common practice.

e Young Opuntia cladodes are chopped and used as vegetables.

f When these terms were elicited they referred to the effect of Opuntia over them.

g The plant mucilage is employed as adherent for fumigation.

Table 3. Values of ecosystem goods and services of production and habitat functions provided by Opuntia scrubland in Ayacucho.

Collected product from Opuntia Scrubland		Average value/ha/year (NS)[a]
Production Function		
Cochineal production		
Harvested cochineal (kg/ha)	65.73 (41.67)	690.20
Price of cochineal (NS/kg)	10.5	
Fruit production		
High quality fruit (boxes/ha)	34.82 (36.79)	322.06
High quality fruit price (NS/box)	7	
Lower quality fruit (boxes/ha)	17.40 (16.3)	
Lower quality fruit price (NS/box)	4.5	
Fodder production		
Total cattle profits (NS)	537.30 (648.95) x 0.3	235.58
Fuel production		
Area of habilitated scrubland per household (ha)	0.97 (0.71)	188.97
Labor (Days employed collecting fuel /ha)	18.89 (9.05)	
Daily Wage rate (NS)	10	
Ornamental production		
Average income from handicraft sale[b] (NS)	50.62	39.71
Area used for collection of raw material for craft making (ha)	1.38 (0.46)	
Total Production Function		*1,476.52*
Habitat Function		
Infestation		
Labor (Days employed in infestation/ha)[c]	52.95 (46.13)	529.95
Daily Wage rate (NS)	10	
Total Habitat Function (3 infestation per year)		*1,589.85*

[a]NS: Nuevos Soles; [b] This corresponds to eight households that reported some handicraft activity; [c] This corresponds to 13 households that reported having infested Opuntia scrublands.

Table 4. Definition and sample descriptive statistics of variables used in the Contingent Valuation analysis regarding the regulation functions provided by the Opuntia scrubland.

Variable	Definition of variable	Mean	Standard Deviation	min.	max.
DEPEN	Ratio members aged (15-60)/household size	0.66	0.23	0.25	1
HEADAGE	Age of the head of the household	40.57	11.57	22.00	72.00
LITERACY	Dummy variable: 1 if the head of household is able to read dependant; 0 otherwise	0.08	0.27	0	1
SCHOOL	Number of years of formal education.	3.97	2.11	0.10	9.00
CULTDOM	Number of elicited elements of the Opuntia cultural domain	5.73	1.42	3.00	9.00
FARMINC	Income obtained from farming activities.	82.76	11.75	41.01	94.80
Categorical variables					
W1.bid	The bid multiplicated by the poverty dummy (1 if the household is below the subjective poverty line; 0 otherwise).	0.77	0.69	0	2.00
W2.bid	The bid multiplicated by the poverty dummy (1 if the household is above the subjective poverty line; 0 otherwise)..	0.33	0.58	0	2.00
Dummy variables					
NODEPEN	Dummy variable:1 if the household has no dependant; 0 otherwise	0.22	0.42	0	1
MIGRATION	Dummy variable:1 if a household member is migrant; 0 otherwise	0.27	0.44	0	1
GENDER	Gender of the head of the household. 1 if male; 0 if female	0.86	0.35	0	1
EROSION	Percepcion of erosion: 1 if the head of household has perceived erosion; 0 otherwise.	0.35	0.48	0	1

Sample size: 113 households.

Table 5: Parametric Binary Logit Model of the Determinants of the Willingness to Pay for Erosion Control Service by Opuntia scrubland.

Variable	Coefficient	Marginal Effect	t-ratio
CONSTANT	-32.66	-7.19 ***	-3.44
GENDER	-1.49	-0.33	-1.14
DEPEN	6.96	1.53 **	2.40
NODEPEN	-3.45	-0.76 **	-2.16
MIGRATION	2.94	0.65 *	1.85
HEADAGE	-0.03	-0.01	-0.48
LITERACY	2.04	0.45	1.14
SCHOOL	0.36	0.08	1.32
EROSION	2.35	0.52 **	2.22
CULTDOM	0.16	0.03	0.55
FARMINC	0.38	0.08 ***	3.90
W1	-3.33	-0.73 ***	-3.90
W2	-3.81	-0.84 ***	-3.57
Log likelihood function	29.54		
Restricted Log likelihood	75.54		

***: Statistically significant at P<0.01; ** Statistically significant at P<0.05; * Statistically significant at P<0.10;

Figure 1: Multidimensional scaling of the core elements of the cultural domain of Opuntia scrublands.

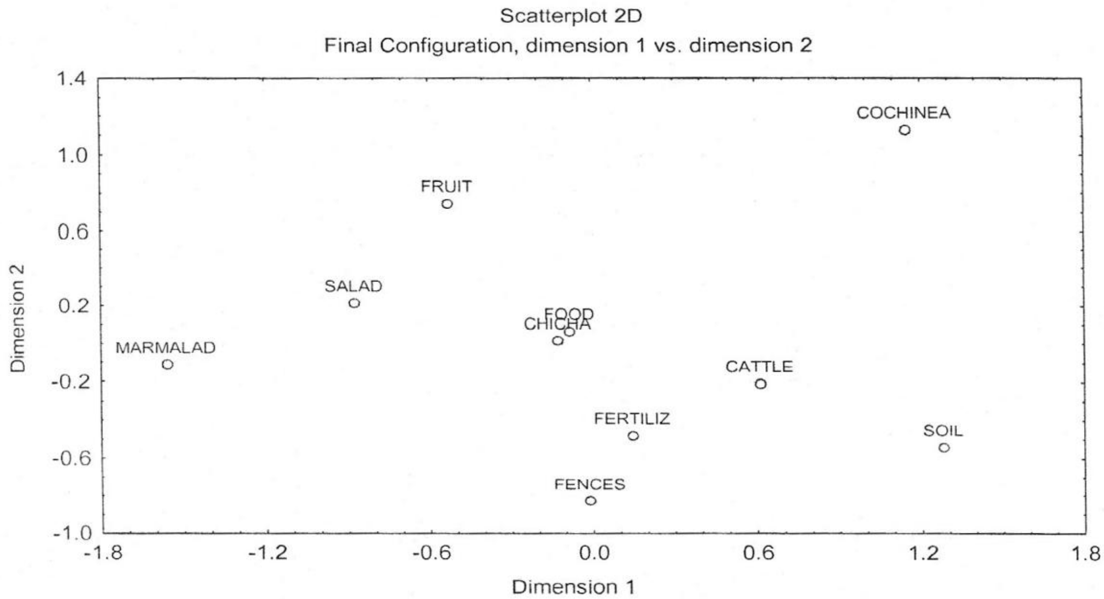


Figure 2: Cluster analysis of the elements of the cultural domain

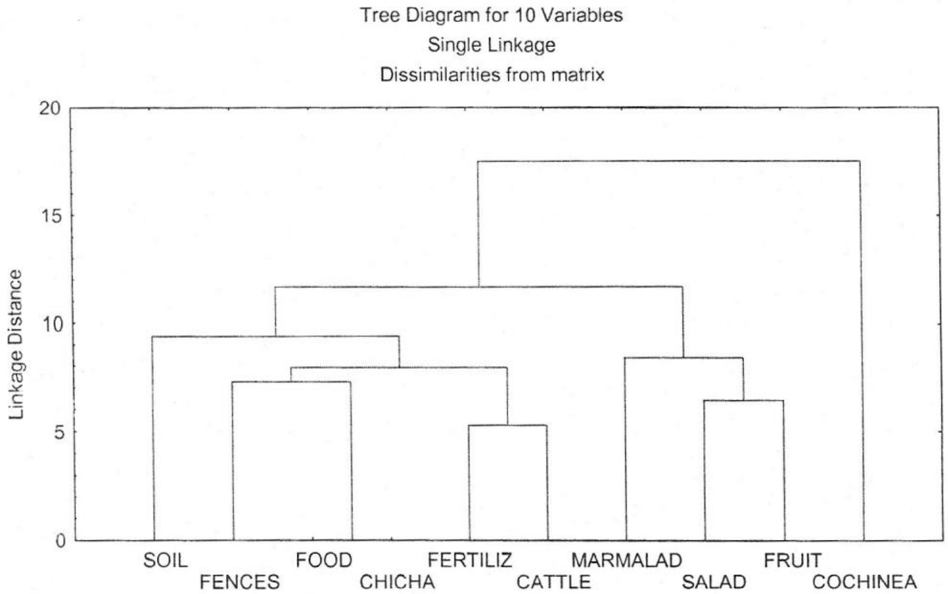


Figure 3: Participation of collected items from the scrubland on peasants'income.

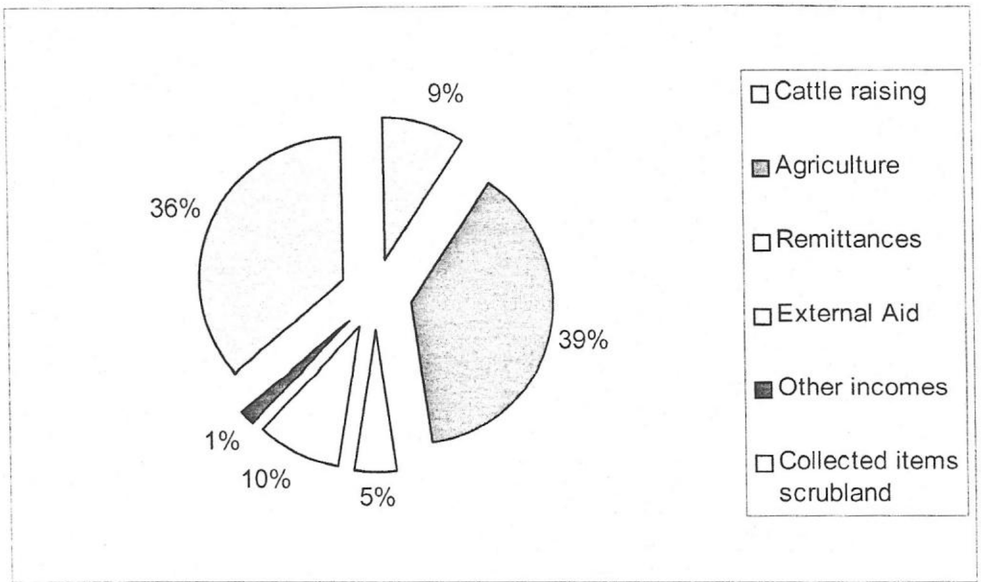
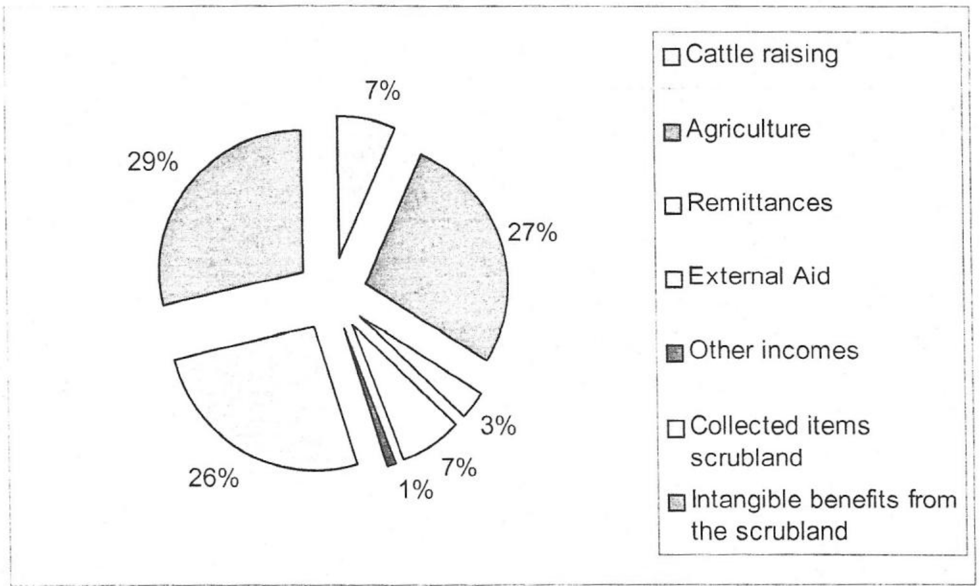


Figure 4: Participation of goods and services provideded by the Opuntia scrubland on peasants well-being.



Anexo 2

Capital social y habilitación de tunales silvestres en Ayacucho, Perú. [Social capital and Opuntia scrubland habilitation in Ayacucho, Peru]

Social capital and Opuntia scrubland habilitation in Ayacucho, Peru

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Abstract

Opuntia scrublands are important ecological-economic systems in the Andean area. Opuntia provides a variety of products employed in the human diet and in animal feed, as well as cochineal insects, a highly valued source of dyes. Land clearance on the scrublands promotes changes in land use, from non-productive wilderness to cochineal and fruit harvest areas, grazing lands, and fuel-wood supply zones. Although an extensive literature addresses the determinants of land clearance actions, little is known about the role of social capital on these actions. Here we explore the role of social capital on land clearance, based on a case of study of Opuntia scrubland habilitation in Ayacucho, Peru.

Keywords: Social capital, Peru, Opuntia, cochineal, land clearance.

1. Introduction

Opuntia scrublands are part of one of the most important socio-ecosystems in the Andean area. The vegetation cover performs a major environmental role protecting slopes against erosion and flooding, as well as improving the levels of soil humidity and soil retention capability (Le Houérou 1996). The Opuntia scrubland provides a variety of non-timber products such as fruit and young cladodes used for food (Pimienta-Barrios 1994), succulent fodder for animal feed (Guevara et al. 1996), and raw material for the manufacture of ornamental and rustic work (Pardo 2002). However, Opuntia scrubs are especially important because they are hosts for cochineal insects. These insects are the source of carminic acid, a natural dye used in the food, textile, and pharmaceutical industries. Collection of the insects has represented an important economic activity for local communities in the Andean area and Mesoamerica since pre-Columbian times. During the period of Spanish domination, the insects were collected as a tribute from small family plots where their host plants were interspersed between subsistence crops. Cochineal was a Spanish monopoly and represented the second export product of the American viceroyalties after silver. The importance of cochineal persisted until the 1870's when synthetic anilines dyes became cheaper and brought on the decline of the cochineal industry. After the ban of some synthetic dyes due to their negative secondary effects, the market is again considering the use of natural dyes. As a consequence, cochineal production has experienced a revival. Peruvian production grew to represent between 85 to 90% of the global market, mainly based on collection of the insect in natural Opuntia scrublands located in the Andean areas of Ayacucho. Due to the favorable environment for both the insect and its host plant, cochineal collection in Peru has a considerable social and economic importance, representing a source of income for some 100,000 peasant families (Flores-Flores and Tekelenburg 1995). These families inhabit poor communities exposed to social vulnerability, disruption of livelihoods, and loss of security as consequence of 12 years of violence by the actions of groups like Shining Path, armed peasant patrols and the Peruvian army (Fumerton 2001).

Current government policy in Ayacucho is focused on poverty alleviation, reconstruction, and repopulation mainly based on distribution of subsidized food, creation of social infrastructure, and support to education, health and sanitation works (PROMUDEH 1997). NGO's and official institutions are promoting productive activities in communal lands including the participatory management of the Opuntia scrubland for cochineal collection. These scrublands, comprising 38,000 hectares in the Andean slopes of Ayacucho, are dense natural formations where cacti of the genera *Cleistocerus* and *Azureocereus* and specimens of *Schinus molle* (Anacardiaceae), *Caesalpina tinctoria* (Caesalpinaceae) and *Agave americana* (Agaveaceae) are interspersed among the dominant species, *Opuntia ficus indica* (Cactaceae), which reaches stand densities over 2000 plants/ha as the slope increases (Piña-Lujan 1981).

The participatory strategy considers support the communal organizations by providing assistance to the local committees of cochineal collectors, by improving the capacity of peasants to supply cochineal through promoting habilitation of the scrublands, and by increasing profitability of the activity through avoiding intermediary traders.

Opuntia scrubland habilitation comprises the opening of access trails, pruning spiny bushes and clearing land to facilitate cochineal harvest and obtaining fuel-wood and fodder from the associated vegetation without affecting the arable layer of the soil. In this sense, since scrubland habilitation involves household decisions, it has much in common with other land clearance activities such as tropical deforestation or mangrove conversion. Hence, many of the numerous analyses and approaches used in these studies may be applicable, for example the effect of output prices and rural wage on the conversion rate of land (e.g. Barbier and Burgess 2001), the influence of socio-economic characteristics of the agents involved in land clearance, such as income level, household size or education (e.g. Lopez 1997, Godoy and Contreras 2001), as well as the effect of spatial and institutional factors such as distance and accessibility to forest areas, land conflicts, or property rights (e.g. Nelson et al. 2001, Cropper et al. 2001). Interestingly, to our knowledge, the effect of social capital on land clearance has not been addressed.

Social capital is a broad concept that captures the idea that some features of social organization such as networks, norms and social trust facilitate co-ordination and co-operation for mutual benefit (Putnam 1995). There is growing evidence of the positive effect of social capital on development actions (Grootaert and van Bastelaer 2002, Isham et al. 2002), as well as on actions related with environmental tasks such as watershed management, irrigation and water use, or participatory forest management (Pretty and Ward 2001, Katz 2000).

The Andean communities have a long history of communal work, reciprocity, and common resources management (Gonzáles de Olarte 1984, Cotlear 1989, Trawick 2001). Ayacucho exhibits a high level of communal organization evidenced by the elevated number of associations, and their capacity to mitigate risk and generate collective actions (CTAR 2001). In this regard, the promotion of scrubland habilitation for cochineal collection and the existing social structure in their communities make Ayacucho an ideal case to test the effect of social capital on land clearance.

In this article, we investigate the role of social capital on Opuntia scrubland habilitation. The structure of the paper is as follows. The next section provides a few guidelines of social capital issues relevant to the problem and a brief background of cochineal collection industry. Section 3 defines the variables considered in the analysis and presents the estimation of the model. Finally, Section 4 discusses the results.

2.Background

Any form of capital represents an asset that produces a stream of benefits. Social capital, like other forms of capital, is productive making possible the achievement of certain goals that in its absence would not be possible (Coleman 1990). Social capital is not a single entity but a variety of multidimensional entities. Thus, the concepts of bonding and bridging social capital (Gittell and Vidal 1998), and the construct of (Uphoff and Wijayaratna 2000), focusing on structural and cognitive forms of social capital, are important in the understanding that contrarily to human capital which resides in individuals, social capital resides in relationships (Lin 2001). Bonding social capital refers to links between people, which facilitate intragroup interaction and collective action, while bridging social capital reflect the links between groups and other actors and organizations (Narayan 2002). Structural social capital is an arrangement of roles and social networks supplemented by rules, procedures and precedents that facilitate information sharing, decision-making, and collective action. Cognitive social capital is a more subjective and intangible concept referred to shared norms, values, trust, attitudes, and beliefs (Uphoff and Wijayaratna 2000). From a point of view of the consequences of social capital rather than its sources, social capital is a subset of social interaction processes which generates durable externalities. Collier (2002) recognizes three types of those externalities: i) information about the behavior of other agents, which is reflected in knowledge about their reliability, hence, in a decrease of transaction costs; ii) information about the non-behavioral environment, that is evidenced in sharing knowledge in order to take better allocative decisions and iii) collective action, which mitigate risks, lower transaction costs, and enable the management of common pool resources, and economies of scale.

For empirical purposes social capital is measured using proxy variables, nevertheless there is no consensus about which are the best proxies (Grootaert and van Bastelaer 2002). Social capital indicators differ geographically and sectorally, and the decision for the selection of proxies is often inspired by the specific outcomes of the social interaction. Thus, membership in networks, meeting attendance, labor input, and participation rate are some of the most frequently used proxies for social capital. The number and types of relations among agents and the characteristics of the group such as heterogeneity of composition, inequity level, or leadership features have also been employed as proxies in several studies (Grootaert and van Bastelaer 2002, Isham 2002b).

Along the Peruvian Andes, the main and more extended form of social organization in the rural villages is the "*comunidad campesina*" (peasant community). A community is a group of families tied together by consanguine or symbolic patronage relationships, which communally own a defined territory, where for productive purposes land is allocated into communal and individual family plots. Communal holdings are communally farmed in an obligatory basis, while individual plots are mainly exploited using family labor force and reciprocity relationships in the communal network. In Ayacucho, there are 452 recognized *comunidades campesinas* that own 72% of the agricultural land available in the region (INEI 1996). The community not only possesses productive dimensions, but also provides a sense of belonging and identity to their members, and generates the social structure needed to develop collective actions such as infrastructure building, or common resources management. The high level of communal organization in Ayacucho is evidenced by the large number of producers committees, peasants associations, and other social groups existing within and outside the community. Some of these groups such as women associations, glass of milk committees, and community kitchens are vital for the subsistence of their members by promoting responses to mitigate the risk of famine and creating bridges with donors (CTAR 2001). The extraordinary capacity of communities in Ayacucho to promote collective actions was evidenced by the peasant initiative to create armed peasant patrols to combat Shining Path in various parts of the region. Through time, in some communities these organizations have exhibited flexibility, often diversifying they role from self-defense to involvement in infrastructure construction or resource management activities such as regulation of the access to Opuntia scrubland for cochineal collection (De Gregori et al. 1996).

2.1 Cochineal production

Cochineal collection is a source of income for Andean peasants. Annual world production of cochineal in 2002 was estimated as 1045 tons. The Peruvian production was over 885 tons, of which nearly 40% was collected from Opuntia scrublands in Ayacucho (PRA 2002). Cochineal is a source of carmine and carminic acids, a group of highly valued dyes in the food, cosmetic and pharmaceutical industries of the United States, the European Union, and Japan. The Peruvian production of cochineal and its dyes has increased in the last twenty years although the price of cochineal has oscillated (Figure 1). The high prices motivated the interest to expand the cochineal industry into other countries. Highly technified plantations were initiated in northern Chile and plans were developed to promote cochineal collection in Bolivia and Mexico (Sáenz 1998), as well as to introduce the insect in the Kalahari Desert in Southern Africa as part of poverty alleviation programs (ADF 1999). Currently, the cochineal price is under 12 US$/kg and many of the commercial firms that initiated Opuntia plantations in order to produce the insect and its dyes are constraining their production (PRA 2002). Nevertheless, cochineal in Ayacucho is still an important product. Due to the small size of individual harvests, there is a long chain of intermediary traders between the producers and the export companies. Peasants are regularly visited by traders who buy cochineal and develop arrangements for future transactions. These traders accumulate cochineal stocks and dispatch them to more wealthy traders in Lima who gather and sell larger stocks to export companies.

In spite of current low prices, government institutions and NGOs are promoting actions based on cochineal collection in extreme poverty areas of Ayacucho. These actions are focused on generating sources of income, incorporating marginal lands into productive activities by habilitating Opuntia scrublands, enhancing the communal organization by supporting local producers committees, and increasing the profitability of cochineal collection by improving the trading channels from producers to export companies.

3. Definition of variables and empirical estimation of the model

An important area of research into land clearance consists in the statistical analysis of the factors determining declining vegetation cover. Several reviewers (e.g. van Kooten et al. 1999) have synthesized many different study cases, and a set of factors that have potential importance on the land clearance processes have been identified. Thus, the analyses of land conversion models have tended to confirm the hypothesis that land conversion is positively related to ouput prices and decreases with high rural wage rates (e.g. Barbier and Burgess 1996). Competing land use models (e.g. Barbier and Burgess 1997), indicate that increasing population density increases vegetation clearance, whereas rising income per capita and agricultural yields reduce the demand for vegetation conversion. The accessibility and distance to the forest areas and some socio-economic characteristics of the involved agents such as household size and education have been also evidenced as factors affecting the land clearance process (e.g. Crooper et al. 2001, Godoy and Contreras 2001). Recently, some empirical analyses have begun to explore the effect on land clearance of institutional factors such as land use conflict, security of ownership, property rights or political stability (e.g. Alston et al. 2000). Although institutional models have demonstrated the importance of these factors in determining land clearance, the judgment concerning the weight given to such factors compared to explanatory variables identified by other approaches is still a research topic.

Since each model is able to produce its unique insight into possible factors explaining land conversion, an interesting issue is to construct synthetic models based on previous approaches in order to avoid the effect of omitting potentially important explanatory variables (Barbier and Burguess 2001). In this sense, data refering to many of the potential factors affecting scrubland habilitation were collected in six villages of the province of Huamanga, one of the most important areas of cochineal collection in Ayacucho.

Since this was a cross sectional study and we focused on villages within a limited geographic area having similar environmental and socio-economic characteristics, no differences were found in the cochineal price and wage rate among villages or between households in the community; consequently, these variables were not considered in the study.

Given the difficulty to define and measure social capital, we chose some proxy variables relevant to Ayacucho and to the desired output in order to evaluate scrubland habilitation. Putnam (1993). used membership in formal associations, voter turnout, and newspaper readership, as proxy variables for social capital. Nevertheless, some of them are not applicable since newspapers do not arrive to the communities, and the voter turnout is not useful because the electoral system was affected during the years of local internal conflict. Membership in formal associations was selected as a proxy variable. This variable was demonstrated useful in other studies of social capital in the Peruvian Andes (Swinton 2000, Swinton and Quiroz 2002). Although many of these associations were set up originally by external agencies, they constitute voluntary organizations if people consider them as such (Paldam 2000). Furthermore, Bebbington (1997) recognizes external agencies as capable of inducing the formation of social capital in Andean communities; hence, membership in associations was considered in the study without distinction of their origin. Participation rate and meeting attendance have been used as proxy variables for social capital in several studies covering issues as diverse as education, agriculture, credit access, humanitarian assistance or watershed management. (e.g. Gugerty and Kremer 2002, Grotaert et al. 2002, Narayan 2002). These variables were considered relevant to the problem at hand, and were included in the analysis. Group characteristics such as heterogeneity, ethnic affiliation, or kinship have been used in several studies as proxies for social capital (e.g. Isham 2002a, Gugerty and Kremmer 2002, Grootaert et al. 2002). Since kin-based groups are the basis of the social organization in the Andean communities, as was emphasized by Bebbington and Carroll (2002), a kinship variable was considered useful to understand internal bonding in the communities and was consequently included in the study. Leadership is considered an important variable that can accelerate the diffusion of innovations and has been used in other studies involving social capital (Isham 2002b). Since Opuntia habilitation is in part externally promoted, it may incorporates elements of innovation; hence, we considered a leadership variable in our analysis.

Along with these proxies for social capital, complementary household socio-economic variables such as age, gender and income were included in the study, as well as scrubland area habilitated and density of Opuntias in the cleared plot. Table 1 lists the variables considered in the analysis.

Since the habilitated scrubland is a variable censured at zero, the general approach for data analysis was to estimate the effect of the social capital variables on vegetation clearance using a tobit model with the area of habilitated scrubland as a dependent variable. The estimated tobit model presented in Table 2 shows that the age of the head of the household, the number of associations to which the household is affiliated, as well as the participation rate in the committee of cochineal collectors and the number of days employed in the habilitation, all have a positive and significant effects on the amount of habilitated scrubland. Other social capital variables such as leadership and kinship were not significant. The density of Opuntia in the scrubland as a proxy for land quality and accesibility has non-significant effect on the habilitation. Other sources of income out of the farm and a larger income from agriculture are also non-significant on the scrubland habilitation.

4. Discussion

The results of the analysis show that the age of the head of the household significantly affects scrubland clearance. In Ayacucho, as in many parts of the Andes, land is scarce and its tenure is a cyclic phenomenon of accumulation and release in synchrony with the age of the head of the household (Ossio 1992). Younger peasants have smaller land plots mainly located in marginal or slope areas and much of their labor force is sold to wealthier peasants or they are involved in temporal migration for non-skilled occupations mainly in the tropical forest of Ayacucho (IER 1985, Pérez Liu 1988). Older peasants stay in the community; hence, they need to be involved in local activities that represent alternative sources of income, such as habilitation of the scrubland for cochineal collection.

As expected, the number of days employed in the habilitation is a positive and significant variable. The participation rate in the cochineal collectors committee has a positive and significant effect on the amount of scrubland cleared. Although the participation in the committee has substantial costs including the time committed to attending meetings, it also has benefits including the diffusion of knowledge from other peasants, and from extension activities or demonstrative events. Group attendance help members obtain information related to Opuntia and cochineal such as market prices or trading arrangements, as well as information about the behavior of other collectors and intermediary traders, all of which are reflected in lower transaction costs and lower searching costs that consequently diminish the costs of habilitation.

Different studies do not necessarily agree with the effect of a selected indicator of social capital, since the results may depend of the outcome variable considered, as well as the level of analysis, the geographical area and historical factors (Bebbington 1999, Grootaert and van Bastelar 2002). The household number of memberships in associations positively and significantly influenced habilitation of scrubland. This proxy variable was also significant in explaining the adoption of sustainable farming and grazing practices in the Peruvian Andes (Swinton 2000, Swinton and Quiroz 2000), and some indexes that combine membership were also significant, evaluating the effect of social capital on household expenditure in other areas like Tanzania (Narayan and Pritchet 1999). On the other hand, Krishna and Uphoff (2002) did not find a correlation between the number of associations and the Index of Common Land Development that they constructed in India, but considered that the relatively low number of associations made this variable not relevant in their area of study.

In this part of the Andes, after the years of war, there are an elevated number of government agencies and NGOs working with funds of external donors and focusing on strategies of rural development, microcredits for agriculture, food security, and human assistance. Many of these external agencies create associations of peasants along the development of their projects, as a strategy to promote communal work and to efficiently distribute the aid (e.g. Díaz et al. 2000). Due to the scarcity of resources, extension agents promote household affiliation to as many associations as possible, since the membership costs are low or inexistent and the benefits are evident in terms of food security, development of skills, and acquisition of external contacts. In this scenario, with communities under 100 households that continuously interact as part of their traditional livelihood, we should be careful before attributing too much weight to the number of associations as the specific channel that influences the habilitation of scrublands, and should be aware that current or past membership in certain associations could directly influence the habilitation, i.e. membership in microcredit agencies could mean a way to obtain new tools, or previous experience in producers peasants associations help them to develop skills for their more efficient use.

The large statistically significance of the dummy variables for some communities suggests that factors other than those considered in our model affect scrubland habilitation in Ayacucho. Other social capital proxies such as leadership and kinship were not significant and both exhibited the expected positive effect on scrubland habilitation, since leaders are usually persons with higher skills, and households that belong to the dominant kinship habitually have differentiated access to means of production (Bianco and Sachs 1998).

The importance of social capital in the Andes has been evidenced in some successful experiences of external aid agencies promoting development in specific places where environmental conditions offer the possibility of producing particular high-value goods (Bebbington 1997). The results indicate that bridging social capital between local producers and external institutions could be effective in promoting the intensification of the productive activity and adding value to the products by processing or transforming them (Bebbington 1996, Healy 2002). In this regard, cochineal collection in Ayacucho could be a candidate for success, due to the commercial importance of the insect and the possibility of adding value to cochineal, by extracting and transforming the dyes.

Research on social capital has demonstrated its importance for community development but gradually it has become evident that social capital can have negative effects (e.g. Rubio 1997, Paldam and Svensen 2001, Woolcock 2002). The negative effects of social capital may be a consequence of within group actions that imposes costs on non-members (Knack 2002). Land clearance decisions rarely take into account the environmental benefits of conservation such as biodiversity maintenance, watersheed protection or carbon storage, generating a range of negative externalities (Georgiu et al. 1997). From a cost-benefit perspective, Isham (2002a) demonstrates that social capital can have potential negative effects in the expected outputs of a development project, either directly because the expected productivity of a form of social capital is negative, or indirectly if social capital has a negative effect on other productive inputs such as labor, physical, human, or natural capital. In this regard, the habilitation of scrublands could be generating negative externalities as a consequence of altering the vegetation cover, such as increasing erosion or diminishing protection against flooding. The negative effects of these externalities would be evidenced only on the long term due to the temporal and spatial discontinuities between the site where erosion or soil degradation occurs, and the site and the time where the harm occurs. Since the benefits of land clearance are for the group involved in cochineal collection and the negative environmental effects are costs imposed on non-members, the social capital associated with scrubland habilitation could be perverse and a revision of the promotion policy will be needed.

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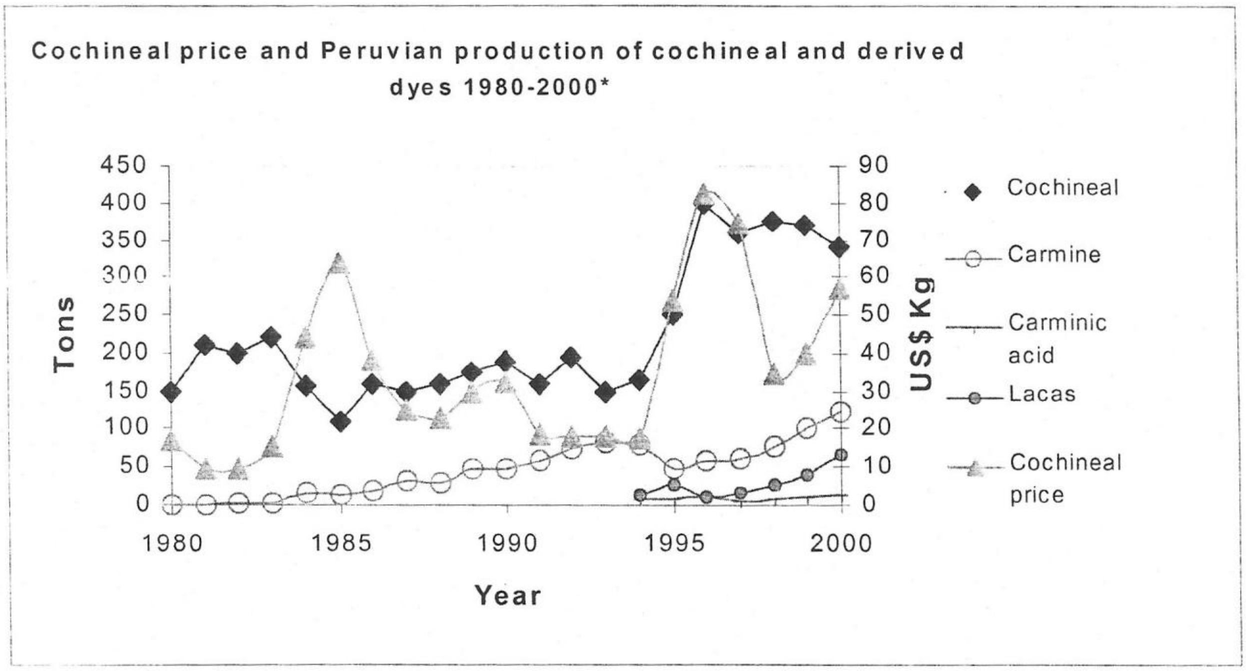
TABLES AND FIGURES

Figure 1. Cochineal price and Peruvian production 1980-2000 (Source PRA 2002)



**The production of derived dyes such as carmine and carminic acid requires a large amount of the total Peruvian cochineal production. Hence, the amount of cochineal in the graphic represents the share of the total production that is exported as dried insects; the rest is included in the graphics as derived dyes.*

Table 1. Definition of variables and selected summary statistics. (N=110)

Variable	Mean	Std. Dev	Minimum	Maximum
Habilitated Scrubland in the last 12 months (Hectares)	1.009	0.70	0	2.9
Age of the head of the household (years)	40.69	11.65	22	72
Sex of the head of the household (binary)	0.85	0.35	0	1
Agricultural income (nuevos soles)	1523.18	680.46	144	4645
OUTFARM (binary), represents if the household obtains income from sources other than farm on a regular basis	0.27	0.44	0	1
Density of Opuntia in the scrubland (plants per Ha)	1294.22	892.35	110	4600
Household membership in associations (units)	5.56	0.93	2	7
Attendance rate in cochineal collectors committee (proportion of total meetings)	0.54	0.26	0	1
Number of days labored in habilitation in the last 12 months (days)	26.68	15.96	0	66
Kinship (binary), represents if the household belongs to the prevailing group in the community	0.47	0.50	0	1
Leadership (binary), considers if in the family group there is a leader in any of the associations	0.3	0.46	0	1

Table 2. Tobit analysis of scrubland habilitation in Ayacucho.

Variable	Coefficient	Std. Error
Constant	-0.87719**	0.402638
Age of the head of the household (ln)	0.180873***	0.066622
Sex of the head of the household (1=male)	-0.00951	0.044239
Agricultural income (ln)	0.004459	0.031703
OUTFARM (dummy)	-0.01848	0.043475
Density of Opuntia (ln)	0.002262	0.019921
Membership (ln)	0.145136*	0.087897
Participation rate in cochineal committee	0.395066***	0.068749
Number of days employed in habilitation (ln)	0.159054***	0.026415
Kinship (dummy)	0.00337	0.034262
Leadership (dummy)	0.013191	0.034737
Dummy community 1	0.123921*	0.066026
Dummy community 2	-0.33893***	0.067771
Dummy community 3	-0.17501***	0.064687
Dummy community 4	0.003349	0.066164
Dummy community 5	-0.22489***	0.060195
Sigma	0.152606	0.010664

Log likelihood function 42.54

***Significant at 1% level, ** significant at 5% level, *significant at 10% level

Anexo 3

Capital social, cambio en el uso del suelo e ingresos campesinos: un modelo de los tunales silvestres de Ayacucho, Perú. [Social capital, land use change and peasants´ income: a model of Opuntia scrublands in Ayacucho, Peru]

Social capital, land use change and peasants' income: a model of Opuntia scrublands in Ayacucho, Peru.

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Abstract

Opuntia scrublands are important socio-ecosystems in the Andean area. Opuntia provides a variety of products employed in the human diet and in animal feed, as well as cochineal insects, a highly value source of dyes. Land clearance on the scrublands promotes changes in land use, from non-productive wilderness to cochineal and fruit harvest areas, grazing lands, and fuel-wood supply zones. In this article, we develop a model to understand the dynamics of this socio-ecosystem in the Andean area of Ayacucho-Peru. The model highlights the role of social capital on land clearance and the effect of the latter on the profits obtained by peasants.

Keywords: *Opuntia*, cochineal, land clearance, land use change, social capital, Ayacucho

1. Introduction

Opuntia scrublands are part of one of the most important ecological-economic systems in the Andean area. The Opuntia scrubland provides a variety of non-timber products such as fruit and young cladodes employed in the human diet, and succulent fodder for animal feeding. Nevertheless, Opuntia scrubs are especially important because they are host to cochineal insects. These insects are the source of carminic acid, a natural dye used in the food, textile and pharmaceutical industries (Le Houérou 1996). The collection of the insect has represented an important economic activity for local communities in the Andean area and Mesoamerica since pre-Columbian times.

Peruvian cochineal production represents between 85 and 90% of the global market, mainly based on recollection of the insect in natural Opuntia scrublands located in the Andean areas of Ayacucho. Due to the favorable environment for both the insect and its host plant, cochineal collection in Peru has a considerable social and economic importance, representing a significant source of income for about 100,000 peasant families (Flores-Flores and Tekelenburg 1995).

After 12 years of violence derived from the actions of Shining Path, armed peasants patrols, and the Peruvian army (Fumerton 2001), current government policy in Ayacucho is focused on a strategy of poverty alleviation, reconstruction, and repopulation mainly based on subsidized food distribution, creation of social infrastructure, and support to education, health, and sanitation works (PROMUDEH 1997). NGOs and official institutions are promoting productive activities in communal lands including the participatory management of the Opuntia scrubland for cochineal collection. This participatory strategy considers supporting the communal organization by providing assistance to the local committees of cochineal collectors, improving the capacity of peasants to supply cochineal by promoting the habilitation of scrubland, and increasing the profitability of the activity by avoiding intermediary traders.

Land cover refers to the attributes of the earth surface and immediate subsurface, including biota, soil, topography, water and human structures (Lambin et al. 2000). In the Andes of Ayacucho, Opuntia scrublands represent ca. 38,000 hectares of sloping terrains covered with a dense vegetation where cacti of the genera *Cleistocerus* and *Azureocereus,* and specimens of *Schinus molle*, *Caesalpina tinctoria* and *Agave americana* are interspersed among the dominant species *Opuntia ficus indica.* The later reaches densities over 2000 plants/ha as slope increases (Piña Lujan 1981).

Land use refers to the purposes for which humans exploit the land cover (Lambin et al. 2000). Opuntia scrubland may be exploited for land uses as varied as cochineal collection, fruit harvest, cattle breeding, or biodiversity conservation. The habilitation of Opuntia scrubland implies altering the land cover by opening trails of access, pruning spiny bushes, and clearing land to promote changes in land use from non-productive wilderness to cochineal and fruit harvest areas, grazing lands, and fuel-wood supply zones, although in Ayacucho these land uses typically overlap (Gade 1999).

There are extensive analyses regarding the effect of output prices and rural wage as drivers of land-use change (cf.Barbier and Burgess 2001). The socio-economic characteristics of the agents involved (e.g. Parks et al. 1998, Godoy and Contreras 2001), as well as the effect of spatial and institutional factors (e.g. Alston et al. 2000, Nelson et al. 2001) have also been estimated. Comparatively, the effect of social capital on land clearance has not been evaluated.

Social capital is a broad concept that captures the idea that some features of social organization such as networks, norms, and social trust facilitate co-ordination and co-operation for mutual benefit (Putnam 1995). Social capital, like other forms of capital is productive, thus making possible the achievement of certain ends that in its absence would not be possible (Coleman 1990). There is growing evidence of the positive effect of social capital on development actions (Grootaert and van Bastelaer 2002, Isham et al. 2002), as well as on actions related with environmental tasks such as watershed management, irrigation and water use, and participatory forest management (Pretty and Ward 2001, Katz 2000). The Andean communities have a long history of communal work, reciprocity, and common resources management (Trawick 2001). Ayacucho exhibits a high level of communal organization evidenced by the high number of existing associations, and their capacity to mitigate risk and generate collective actions (CTAR 2001). Hence, scrubland habilitation represents an ideal case to evaluate the effect of social capital on land use change and peasant income.

Dynamic modeling provides a tool to link ecological and social systems as well as to identify those factors that are important components of the process of land use change from a system's perspective (e.g. Voinov et al. 1999). In this article, we develop a model to understand the dynamics of ecological and socioeconomic systems in the Andean area. Our main aim is the analysis of the relationships between the Opuntia scrubland, and some of its land uses:cochineal collection, fruit harvest, and cattle breeding, highlighting the role of social capital on scrubland habilitation and its effects on the profits obtained by peasants.

Data for the model were obtained during fieldwork in the province of Huamanga, Ayacucho (Rodríguez et al. 2003a,b) and were complemented with records and information available in the literature.

2. Basic structure and data

The model represents the dynamics of the scrubland in the province of Huamanga, one of the most important areas of cochineal collection in Ayacucho. Agriculture is the main economic activity in the province. Land is communally owned, but for production purposes it is divided into communal and individual family plots. Communal holdings are communally farmed on an obligatory basis, while individual plots are mainly exploited using family labor force and reciprocity relationships in the communal network. Land is scarce and production is limited. Family plots are fragmented and small holdings undergo constant division because of demographic pressure and inheritance practices.

The sectors and components of the model and the relationships between them are presented in figure 1. Social capital is an important parameter affecting the habilitation of unproductive Opuntia scrubland. Land clearance promotes changes in land use to cochineal and fruit harvest areas, and graze lands. Opuntia plants produce abundant fruit, cochineal is a parasitic sessile insect feeding on cladodes of Opuntia, and cattle use scrubland vegetation as forage. Peasants obtain benefits from habilitated scrubland by harvesting fruit, collecting cochineal, and breeding cattle.

2.1 Description of model sectors

Figures 2 to 6 present the detailed structure of the model describing the in and outflows between the stocks and sectors.

2.1.1 Opuntia scrubland habilitation sector (Figure 2)

The habilitation process comprises opening trails of access, pruning spiny bushes, and clearing land to facilitate cochineal harvest and to obtain fuel-wood and fodder from the vegetation associated to Opuntia without affecting the arable soil layer. Analysis of field data shows that the age of the head of the household, the number of associations that the household is affiliated to, the rate of meeting attendance in the committee of cochineal collectors, and the number of days employed in the habilitation process are significant variables effecting the amount of scrubland habilitated (Rodríguez et al. 2003b).

2.1.2 Vegetation sector (Figure 3)

The vegetation sector is modeled considering the simplified dynamics of the components of the Opuntia scrubland, i.e. Opuntia plants, grasses and browse. The growth of the vegetation sector was developed considering the availability of rainfall in the area. Based on 10-year records from the nearest climatic station located at Tambillo, Huamanga, the mean rainfall was taken as 759 mm per year. The vegetation growth is not only related to the mean rainfall but also to the dependability of annual rains. Hence, a dependability index, given as the ratio of a given frequency to the mean (Le Houérou et al.1988), was employed and set equal to 0.8 as in other parts of the Andes with similar rainfall records (e.g. Guevara et al. 1996a). A rain-use efficiency factor (RUE), which is the relationship between maximum standing crop at the end of the rainy season (in kg of dry matter /ha /year) and total annual rainfall (in mm/year), was used to estimate the carrying capacity of every component of the vegetation sector, following Guevara et al. (1996a). This seems to be a valid indicator of vegetation type and productivity (Le Houérou et al. 1988). The RUE for grasses was conservatively considered equal to 2.66, which is the mean value for overall productivity in geographic areas with lower levels of annual rainfall, for which data is available (Le Houérou and Hoste 1977). The RUE for browse is usually 1.4, in zones with mean rainfall below 350 mm/year (Guevara et al. 1996a). Nevertheless, similarly to Le Houérou (1989), we used a conservative RUE factor of 1, considering the assumption that wild scrubland is a pristine environment. Based on Guevara et al. (1999), the RUE for Opuntia was conservatively considered equal to 15. The Opuntia productivity (P) (in tons of dry matter/ ha /year) was calculated considering the mean annual rainfall in mm (R), using the relationship P=-2.042+0.025R described by Guevara et al. (2003), and considering it as carrying capacity. The availability as forage of each component of the vegetation sector was evaluated based on both field observations and literature reports. The herbaceous layer accessible to cattle is about 80%, the rest being unavailable because it lies below spine shrub species (Guevara et al. 1996b). Browse availability to cattle is about half the annual yield (Le Houérou 1993). Opuntia consumption in the diet should not exceed 10% of animal live weight when used as a sole feed during the season. The nutrient content of the cladodes is altered as their age increases and cladodes over 3 years old are almost indigestible with no feed value (Le Houérou 1996). Field observations in Ayacucho suggest that at least 30% of the cattle diet is obtained from Opuntia; hence, the availability was considered one third of the total yield. The stock of scrubland forage considers the sum of the portions of each vegetation component available for grazing, the scrubland consumption for cattle, as well as a portion of the vegetation that dries out at the end of the rainy season.

2.1.3 Cattle sector (Figure 4)

Ownership of livestock is suggested as one of the principal basis of differentiation among families in the Andean communities (Montoya 1982). However, this is not necessarily correlated with land tenure due to the use for animal husbandry of crop byproducts such as corn stalks as well as weeds and vegetation growing in public areas such as roadsides (Quijandria 1987) and in Ayacucho Opuntia scrublands (Gade 1999). In many parts of the Andes, cattle are rarely consumed and are raised as a source of cash and as savings to face emergencies (e.g. Cotlear 1989, Valdivia et al. 1996). The cattle sector represents the dynamics of cattle raising in Ayacucho: young cattle are bought, fed with scrubland resources as well as crop byproducts, and sold usually after a year of stocking. Part of the revenue is employed in buying new cattle and maintaining the cycle, while the remnant partially covers the need of cash to obtain goods and services not available in the community. Due to the different animal species involved in cattle raising, we opted to transform the cattle owned by individual households to tropical livestock units (TLU) (Boudet 1975). Following Pieri (1989), one TLU corresponds to one cattle, one horse, five asses, ten sheep, or ten goats. Cattle dry matter requirements were considered based on a diet of 2.5 kg per day per 100 kg of liveweight (Guevara et al. 1996b). Cattle byproducts such as milk were not considered in the study since field work revealed that due to the low quality of the herd and of the diet, the production of milk is limited to two liters per day and occurs only during the two months of the rainy season.

2.1.4 Fruit harvest sector (Figure 5)

Opuntia fruit are rich in water and have a high content of sugar and minerals such as calcium and phosphorus (Yasseen et al. 1996). Fruit yields vary considerably with ecological conditions, the care given to the crop, and the nature of the cultivar. Commercial plantations may reach over 20 tons per year with 400-600 mm of mean annual rainfall (Barbera e Inglese 1993). In the case of non-cultivation, as in hedges and fences, fruit yields may vary from 1 to 5 tons per hectare per year, and commonly yields reach between 5 and 10 tons after tilling and weed control (Le Houérou 1996). Fruit production in habilitated Opuntia scrubland is high. Nevertheless, peasants harvest just a small portion of the available fruit because enormous fruit supply in Ayacucho easily saturates local demand, and due to the inability of peasants to reach the standards of other fruit markets. Hence, most of the fruit gets rotten in the field by the end of the season. The amount of harvested fruit is a function of both the available area of Opuntia and the labor involved in collection. Fruit benefits depend on the quality of the harvested fruit. Quality is related to the ability of the harvester and is not a function of the size of the fruit, since first or second quality fruit differ only in the refinement and cleanliness of the cutting action when harvested, which leads to longer and better fruit life.

2.1.5 Cochineal sector (Figure 6)

Cochineal sector, represents the dynamics of the insect population and the relevant economic relationships. The growth of the cochineal population was described based on the logistic equation (Verhulst 1838, Graham 1935). Intrinsic rate of increase was considered equal to 0.055 (Méndez-Gallegos et al. 1993), while the carrying capacity was defined as a function of both the growing number of available plants as a consequence of scrubland habilitation, and the cochineal infestation level in these plants, which for the area of study we have observed it to be equal to 0.3. The dynamics of the cochineal population was modeled considering the growth of the insect stock and a simplified harvest function, which was defined considering the stock of cochineal, the labor effort, and a catchability coefficient. This latter was defined as the fraction of the population collected by a unit effort (Gulland, 1983), which in the present case, we have evaluated as equal to 0.0033. Following Clark (1985), the derived harvest function assumes that catch per unit effort is directly proportional to the density of cochineal in the scrubland, which in turn is directly proportional to its abundance; hence, variations in insect spatial distribution are ignored. The cochineal sector also considers the cochineal price and costs. The former represents a fraction of the price paid by export companies to intermediary traders, while the costs involve only non-paid family labor. Hence, total cost was calculated based on the local wage rate as a broad measure of the opportunity cost of time. The cochineal sector assumes that harvest technology is fixed, and that the infestation level of the habilitated scrubland is constant. Cochineal price and wage rates, as well as the fraction of price retained by intermediary traders are also assumed constant.

3. Results

3.1.Calibration and validation. Validation procedures depend on the amount of data available and the understanding of the system (Rykiel 1996). A simulation model is considered validated if it provides a correct representation of the real system and accurately predicts the actual data set (replicative validation), or some new or unexamined set of observations (predictive validation) (Power 1993). The calibrated model closely resembles the dynamics of the system under the initial conditions defined in Appendix A. Table 1 shows the output of the model and the observed values for scrubland habilitation, fruit harvest, and cochineal collection sectors. Due to the transformation of the different cattle species to TLU, and the role of cattle breeding as savings for emergencies, and their stochastic occurrence, there are no available data to validate this section of the model by itself. Nevertheless, due to the dynamic dependence between the components of the system, if their outputs fit well with the observed values, we may expect that the cattle breeding sector will not significantly perturb the behavior of the system and the model represents its dynamics with enough accuracy.

3.2 Simulation run. We explored the behavior of the system in a five-year simulation run, a time equivalent to a presidential period in Perú. This short horizon was defined based on the lack of consistency in the policies promoted by different governments, the great number of NGOs working in the area, and the short life span of their sponsored projects. Additionally, due to the lack of coordination between these external institutions, new options are constantly appearing in the communities, and peasants are used to leaving some programs to enroll in the newest one, or to join more attractive projects in terms of food security. Hence, a longer simulation will exhibit a lower predictive capacity and was discarded.

Figure 7 shows that for the current effort level, the stock of cochineal first decreases as a consequence of insect collection and then increases as the Opuntia scrubland is habilitated and new infested Opuntias become available. Assuming an increasing demand, under the same level of effort the amount of harvested fruit increases as the scrubland is habilitated and then remains constant if no additional land is cleared.

The scrubland comprises Opuntia, browses, and several species of grasses. Nevertheless, even if the scrubland is habilitated, not all the vegetation left is suitable for consumption, and there is an increasing amount of available forage that allows the persistence of the traditional form of cattle breeding (Figure 8).

3.3 Sensitivity analysis. A sensitivity analysis allows quantifying the effect of a defined parameter change on a variable. First, we broadly explored the sensitivity of the net present value of the total profits obtained by peasants from cochineal collection, fruit harvest and cattle breeding (NPV) to 10 and 20% change in several parameters considered relevant to each of the sectors taken into account in the NPV, and which may be modified through programs or policies. Later, we expanded the analysis to comprise the effect of the social capital parameters involved in scrubland habilitation on the NPV. Peasant rationality in the Andes is not focused on maximizing the production or productivity of the assets but rather on trying to avoid risks while covering their needs of fuel, food supply and cash for emergency

(Valdivia et al. 1996). Consequently we conservatively assumed an increasing level of effort in cochineal collection, proportional to the scrubland habilitation rate in order to maintain the initial effort level per unit area. The results of the first analysis, considering a discount rate of 10%, are presented in table 2.

Cattle dry matter requirements was one of the parameters selected for the sensitivity analysis. A decrease in this parameter represents that cattle is obtaining forage from sources other than the scrubland, e.g. crop byproducts, while the opposite represents that other sources of forage are less available, as after a poor crop harvest. Changes in this parameter did not significantly affect NPV. Nevertheless, it was considered in the study because although an increase in one TLU is able to exhaust the available stock of scrubland forage (Figure 9), peasants are monetary constrained and an increase in the number of TLU is not likely without external aid. Changes in the magnitude of the use of scrubland resources as forage are more likely.

Three parameters concerning the cochineal sector were selected. One biological parameter (infestation level of the Opuntia plants), a management parameter (cochineal collection effort), and a trading parameter (proportion of the cochineal export price retained by intermediary traders). The infestation level is a parameter that can be increased by artificially infesting the Opuntia plants, a well-known practice in commercial cochineal exploitations (Flores-Flores and Teckelenburg 1995). Contrarily, environmental factors such as wind and rain may severely diminish cochineal populations and infestation level (Moran and Hoffmann 1987). The output of the analysis shows that a 10% change in the infestation level leads to a 3% increase in the NPV of the profits obtained by peasants.

The level of effort in cochineal collection is a parameter that can be altered as a consequence of household decisions. Using a yield-effort curve, the cochineal price, and the effort cost, we built the total sustained revenues and total sustained cost curves presented in Figure 10. The graph shows that increasing the effort level will diminish the net revenues, reaching zero at an effort level *ca.* 40 days. Nevertheless, the sensitivity analysis shows that a 10% increase in the current level of cochineal collection effort leads to a 7% increase in the NPV of the profits obtained from habilitated scrubland.

Cochineal is an important product and due to the small individual harvests there is a long chain of intermediary traders between the producers and the export companies. Peasants receive *ca.* 30% of the price paid by export companies to the last intermediary (Flores-Flores and Teckelenburg 1995, PRA 2002). Several actions are currently being taken to diminish the participation of intermediaries and enhance trading channels. The sensitivity analysis for this parameter revealed that a 10% decrease in the portion of price retained by intermediary traders, increase the net present value of the peasant profits by 17%.

Since there is an enormous supply of Opuntia fruit in Ayacucho, peasants harvest just a small portion of the available fruit before it saturates the local demand. The result of the sensitivity analysis for this parameter shows that a change in the effort level for fruit harvest has a minor affect on NPV.

We expanded the sensitivity analysis to evaluate the effect of social capital on the total peasant profits derived from scrubland habilitation for cochineal collection, fruit harvest, and cattle breeding, after changes of 10 and 20% in the initial values of the selected social capital parameters and, for comparative purposes, in the number of days of labor allocated to scrubland habilitation.

For empirical purposes social capital is measured using proxy variables. Nevertheless, there is no consensus about which variables are the best (Grootaert and van Bastelaer 2002). Social capital indicators differ geographically and sectorally, and the decision for the selection of proxy variables is often inspired by the specific outcomes of the social interaction. Thus, membership in networks, meeting attendance, labor input, and participation rate are some of the proxy variables for social capital. The number and types of relations among agents, and the characteristics of the group such as heterogeneous composition, inequity level, or leadership features have also been employed as proxies in several studies (Grootaert and van Bastelaer 2002, Isham et al. 2002).

Given the difficulty to define and measure social capital, we chose some proxy variables relevant to Ayacucho and to the desired output to evaluate. Based on a previous study (Rodríguez et al. 2003 b), membership in formal associations and meeting attendance in cochineal producers committee were the proxies selected. These variables have been used in diverse issues such as education, agriculture, credit access, humanitarian assistance, or watershed management (e.g. Gugerty and Kremer 2002, Grootaert et al. 2002, Narayan 2002, Uphoff and Wijayaratna 2000), and have been demonstrated significant in the Peruvian Andes (Swinton 2000, Swinton and Quiroz 2000). The results of this second sensitivity analysis are presented in Table 3. The analysis reveals that changes in the social capital variables related with scrubland habilitation have an effect of similar magnitude than labor, on NPV. Increasing any of these parameters causes a faster habilitation rate;

nevertheless, since the available scrubland area for habilitation is limited to two hectares, after a short period of time peasants with lower levels of the selected parameter will obtain the same level of profits after habilitating their total allowable area. Thus, under the current conditions, the sensitivity of NPV to social capital variables or labor is low.

We further explored the change in NPV for the whole range of available values for the social capital and labor parameters. The results are shown in the figure 11. Figure 11a shows that peasants that do not attend any meeting of the cochineal collector committee will have *ca.* 10% lower profits than the peasants that show full attendance. The fieldwork data shows that the total number of meetings varies between communities; nevertheless, the highest number is never above 26 per year. Similarly, peasants that belong to the maximum number of reported associations (8), are able to obtain 4% of additional profits compared with peasants that belong just to the basal association, the "comunidad campesina" (Figure 11 b). Comparatively, figure 11c shows that peasants that on the average allocated 26 days of labor to Opuntia scrubland habilitation, require 13 days of additional labor to obtain similar levels of NPV than that obtained by increasing the values of the social capital parameters.

4. Discussion

The developed model is a tool to understand the dynamics of the Opuntia scrubland system in Ayacucho to a broad range of parameters in the biological, social and economic contexts. Like every model, it necessarily involves a series of simplifications and assumptions due to the complexity of the ecological and economic systems. In that sense, the model can be useful to identify areas where further research is needed. Results suggest that policies and programs focused on increasing the number of cattle heads owned by peasants will be unsuitable because the lack of pasture land and the negative significant effect of an additional TLU on the available scrubland forage. Programs aimed to provide peasants with higher quality cattle which can be sold at greater prices, as well as obtaining cattle byproducts such as milk, by increasing the current level of Opuntia in the diet (e.g. Guevara et al. 2003) might be more appropriate.

The sensitivity analysis shows that increasing the infestation level will increase the NPV of the peasants's profits. The assumption behind this is that the mentioned increase occurs naturally and is free, i.e. no artificial infestation is required. The value of the ecosystem service of nursery and refugium (sensu De Groot et al. 2002) for the Opuntia scrubland in Ayacucho was calculated as 1589 nuevos soles per ha/year (Rodríguez et al. 2003 a). If that amount were considered in the sensitivity analysis, the NPV would decrease after increasing the infestation level. Promoting artificial infestations to increase the cochineal collection and peasants' profits, seems to be a viable option only if the infestation costs are low or inexistent.

The model suggests that under the current conditions, with the cochineal price very close to the wage rate, increases in the effort level of cochineal collection will diminish the net revenues. This could be a valid explanation for the low levels of cochineal harvest compared with the cochineal stock. However, although most of the cochineal collection is done using non-paid family labor, the model assumes that the effort cost is the wage rate in Ayacucho. Therefore, a more accurate measure of the opportunity cost of the time would be useful.

The sensitivity analysis suggests that improving the trading channels between cochineal producers and export companies seems to be among the most readily achievable policies in order to increase peasants' profits. Peasants are regularly visited by traders involved in the commerce of cochineal. These traders buy cochineal and develop arrangements for future transactions in order to accumulate cochineal stocks and dispatch them to more wealthy traders who later transport and sell the larger amount of insects demanded by export companies. In that sense, several NGO's have done efforts to substantially enhance the cochineal gathering system in the communities, by increasing the accuracy in the quantification of the amount of collected cochineal, reducing the adulteration of the product, and diminishing their margin of benefits when acting as traders. Hence, these NGOs are able to buy cochineal at higher prices that ordinary intermediary traders. However, the debate about whether this practice represents ethical trading is open, since most of the NGO's are non-profit organizations and are competing with intermediary trader firms that require profits to subsist.

Although the sensitivity of the labor involved in scrubland habilitation and the selected social capital parameters in relation with the NPV is low, changes in the whole range of available values for these parameters show that a significant increase in the number of days allocated to scrubland habilitation is required to obtain a NPV similar to that derived from increasing the social capital level in a lower magnitude.

In a broad sense this finding highlights the idea that social capital, like other forms of capital, is productive (Coleman 1990) and can be used as input and argument of the production and utility functions (Schiff 1992). However, social capital is not costless and requires an investment – at least in terms of time and effort- that can be significant (Grootaert and van Bastelaer 2002). Therefore, in a cost-benefit framework, although social capital is expected to have a positive effect on NPV, the relative magnitude of this positive effect –at the margin- should be compared with the corresponding expected effects of physical capital, labor and human capital before promoting potential investments in social capital (Isham 2002).

Social capital resides in relationships rather than in individuals (Lin 2001). The social interaction is able to generate positive externalities that are reflected in diminishing transaction costs, knowledge sharing, and promotion of collective action (Collier 2002). For this study case, although the attendance to the cochineal committee meetings has substantial costs including the time commitment in the meetings, it provides benefits including the diffusion of knowledge from other peasants, and from extension activities or demonstrative events. Group attendance helps members to obtain information relevant to the Opuntia and cochineal such as market prices or trading arrangements, as well as information about the behavior of other collectors and intermediary traders that are reflected in lower transaction costs and lower searching costs that consequently diminish the costs of habilitation.

Due to the scarcity of resources, extension agents promote that households affiliate to the highest possible number of associations, since the membership costs are low or inexistent and the benefits are evident in terms of food security, development of skills, or acquisition of external contacts. Besides the mentioned positive externalities derived from the social interaction, current or past membership in certain associations could directly influence the habilitation rate. For example, membership in microcredit agencies could represent a way to obtain new tools, whose use could be more efficient from experience gained in producers peasants associations. Hence, a review of the specific channels through which social capital influences the habilitation of scrublands will be useful.

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Tables and Figures

Figure 1. Conceptual model.

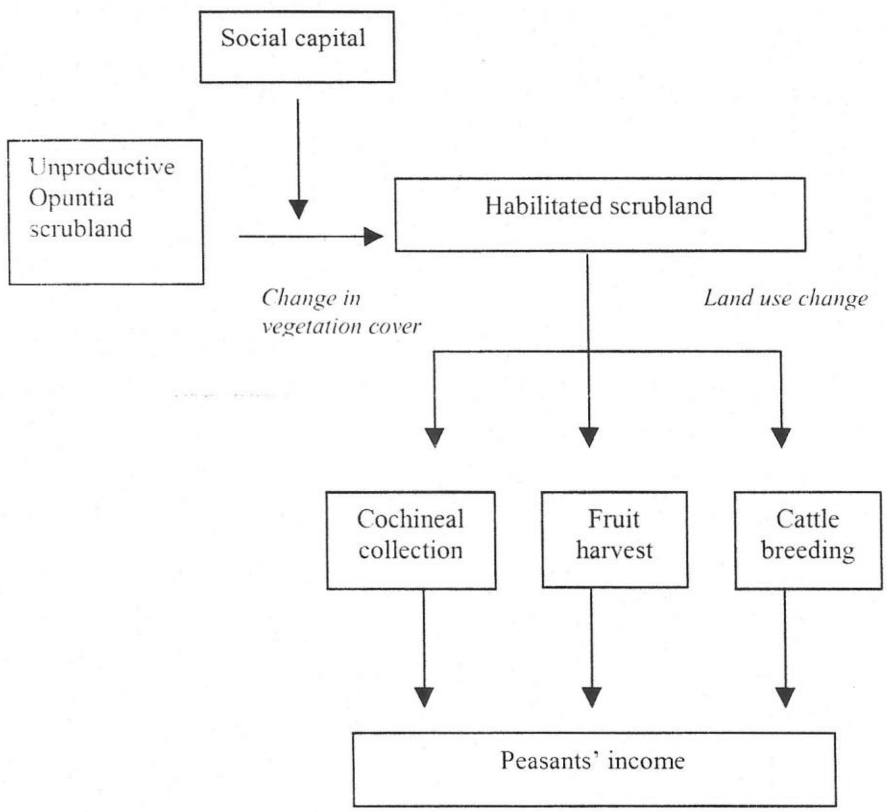

Figure 2. Scrubland habilitation sector

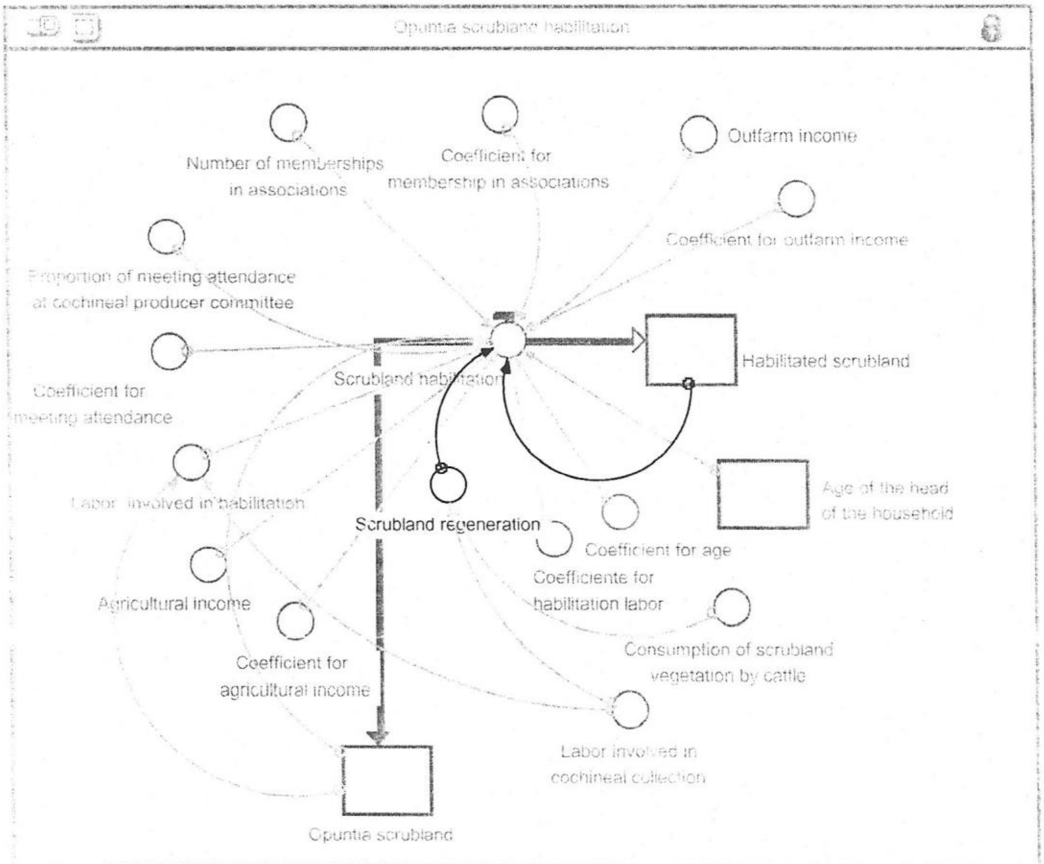

Figure 3. Vegetation sector

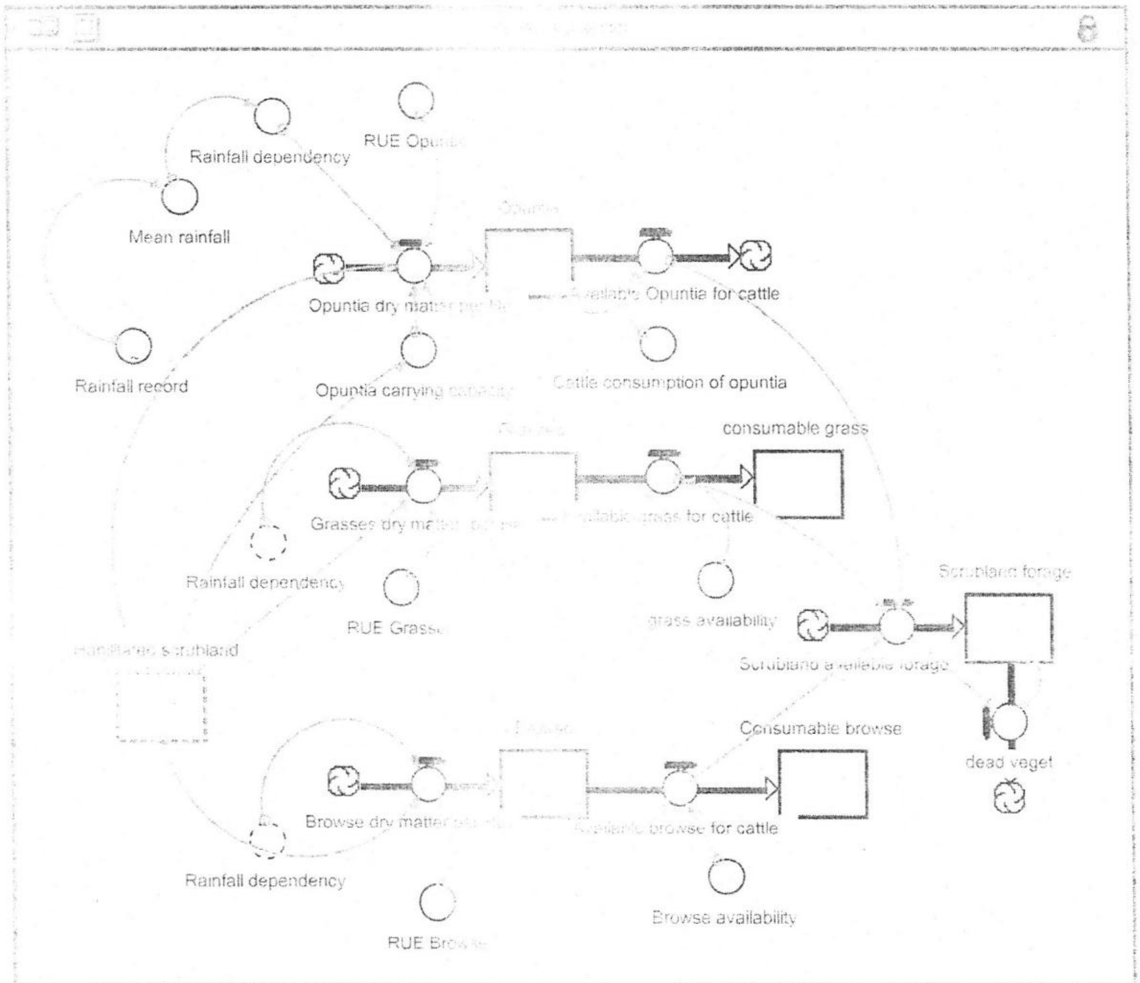

Figure 4. Cattle sector

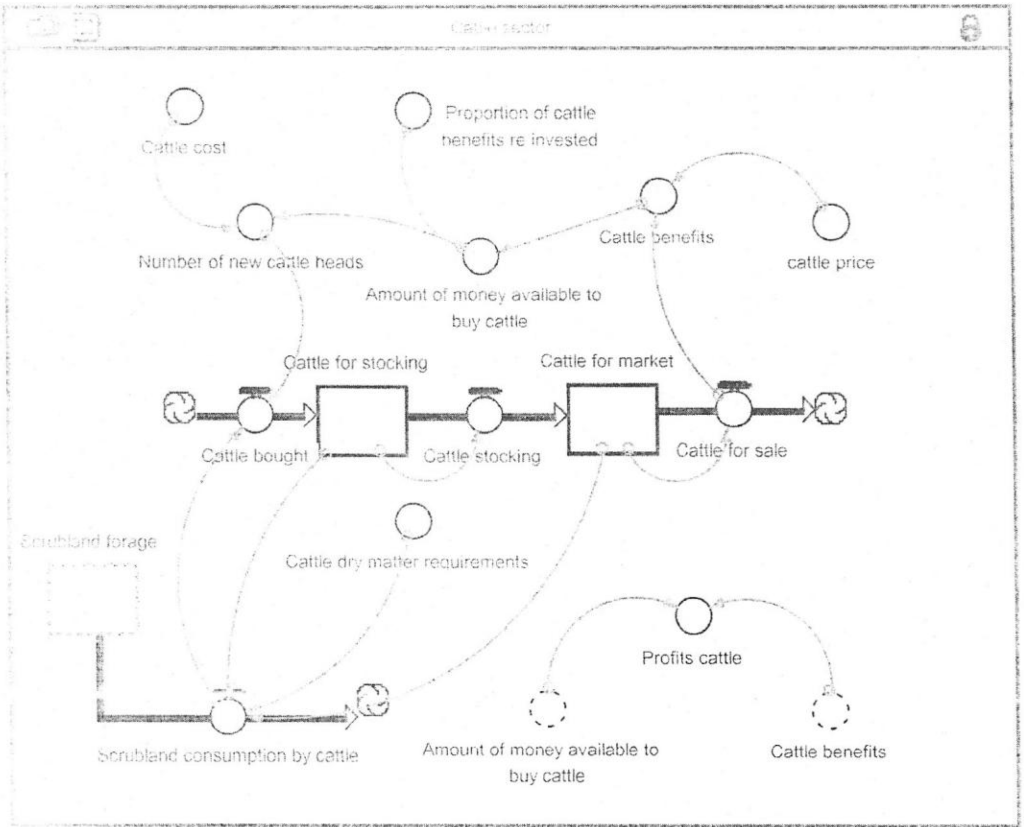

Figure 5. Fruit sector

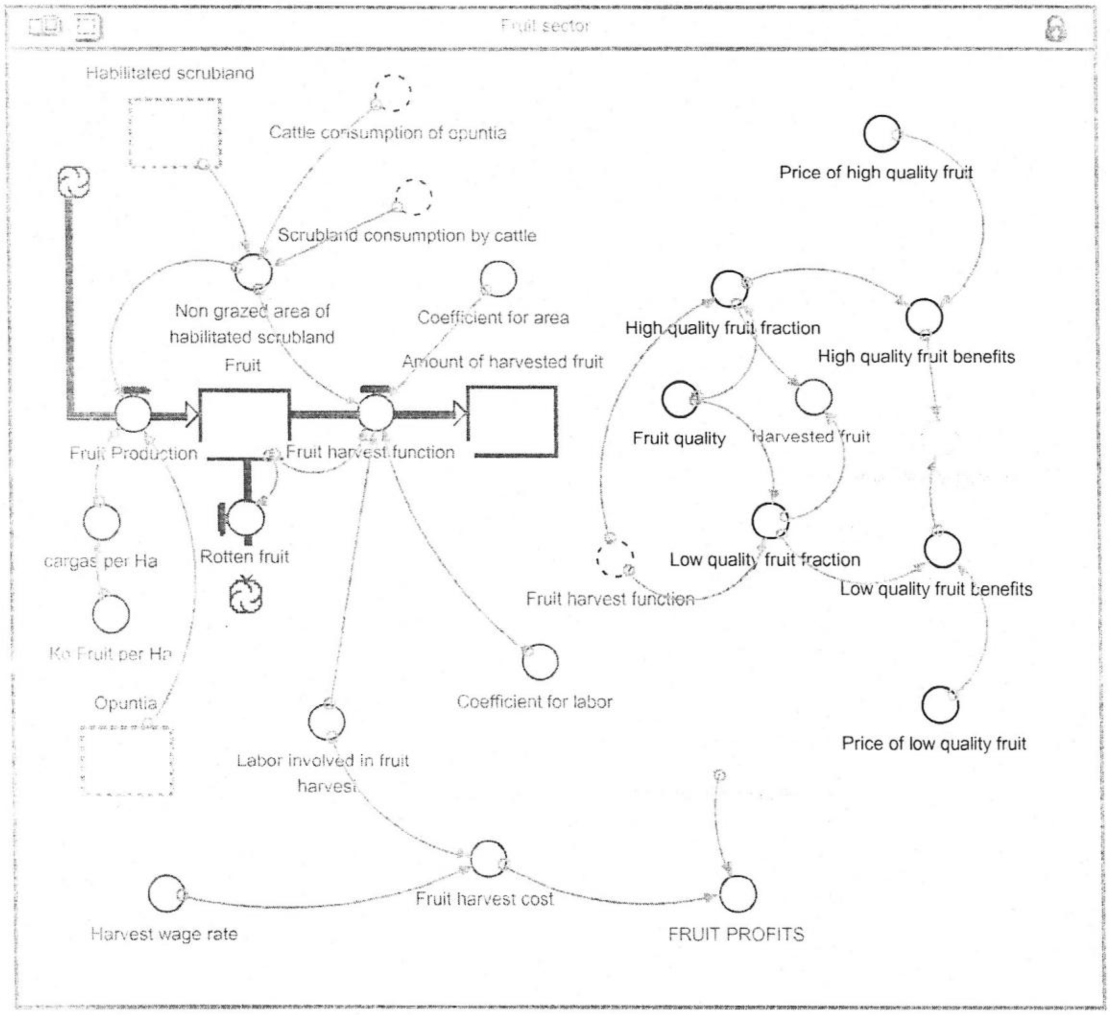

Figure 6. Cochineal sector

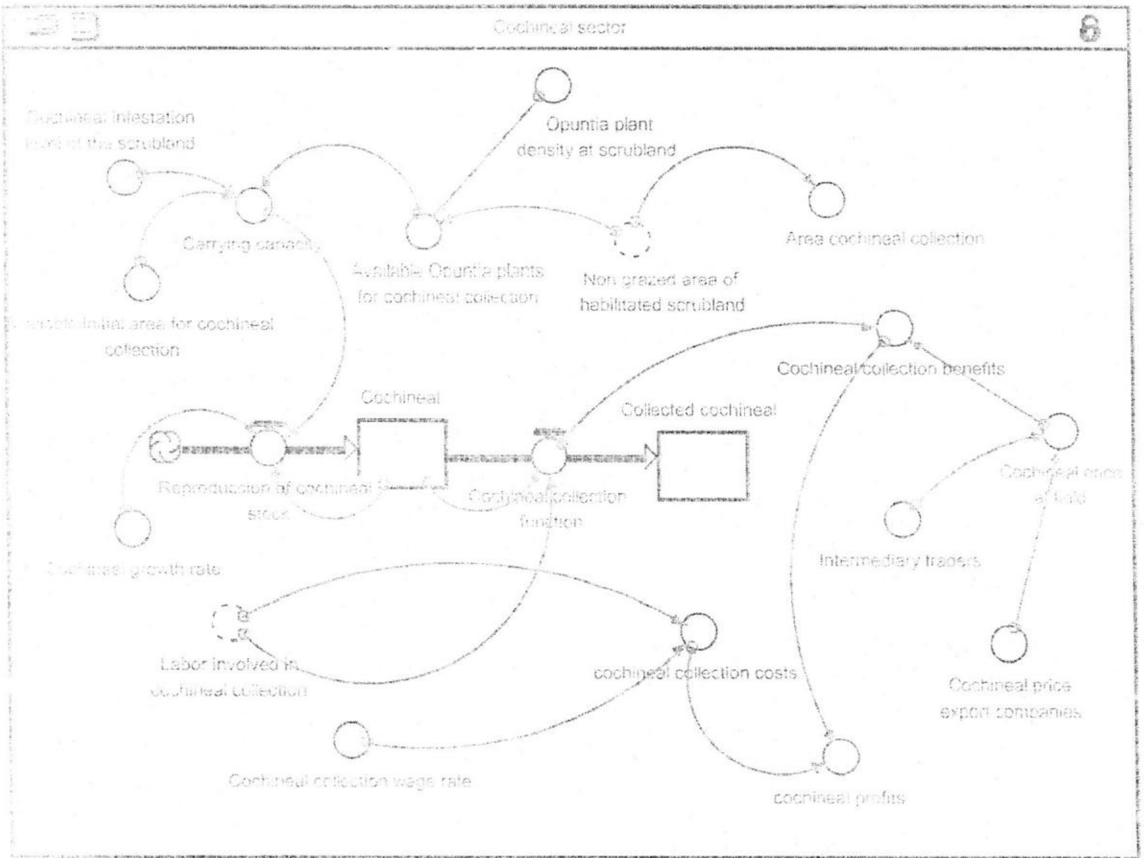

Figure 7. Simulation run under a five-year scenario of the effect of Opuntia scrubland habilitation on cochineal stock, fruit harvest, and available Opuntia for cattle.

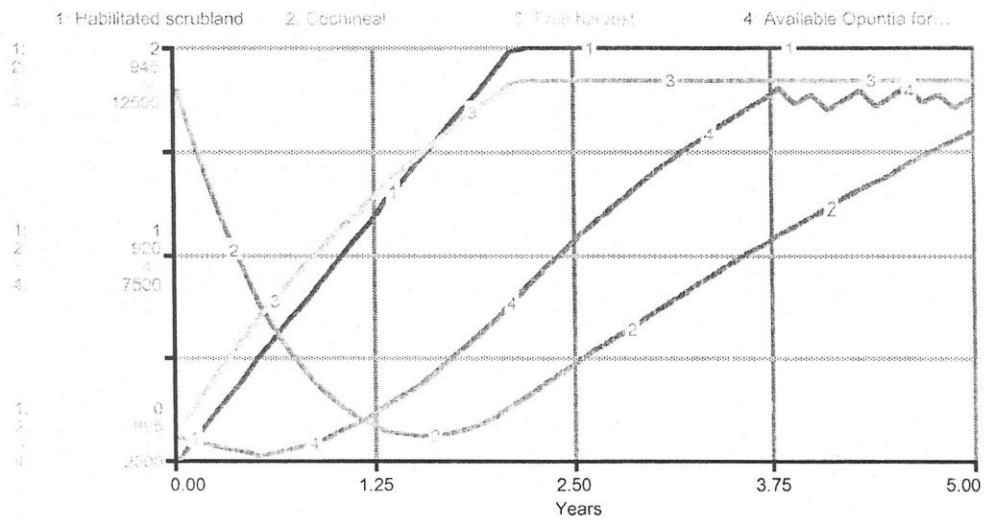

Figure 8. Simulation run under a five-year scenario of the effect of Opuntia scrubland habilitation on scrubland availability for grazing and the amount of cattle for stocking and for market.

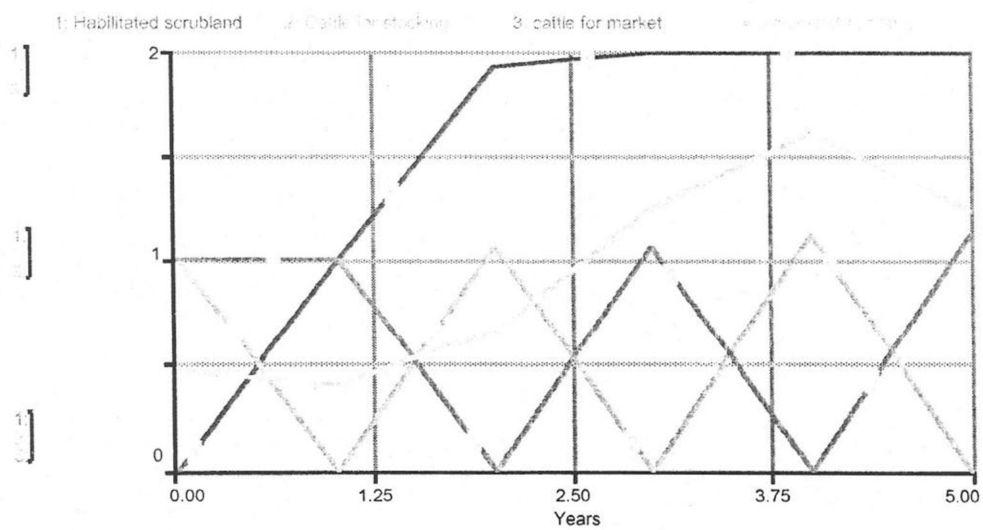

Figure 9. Effect of grazing on the available scrubland forage. Curve 1 represents the current condition, while curve 2 represents the increase of one TLU.

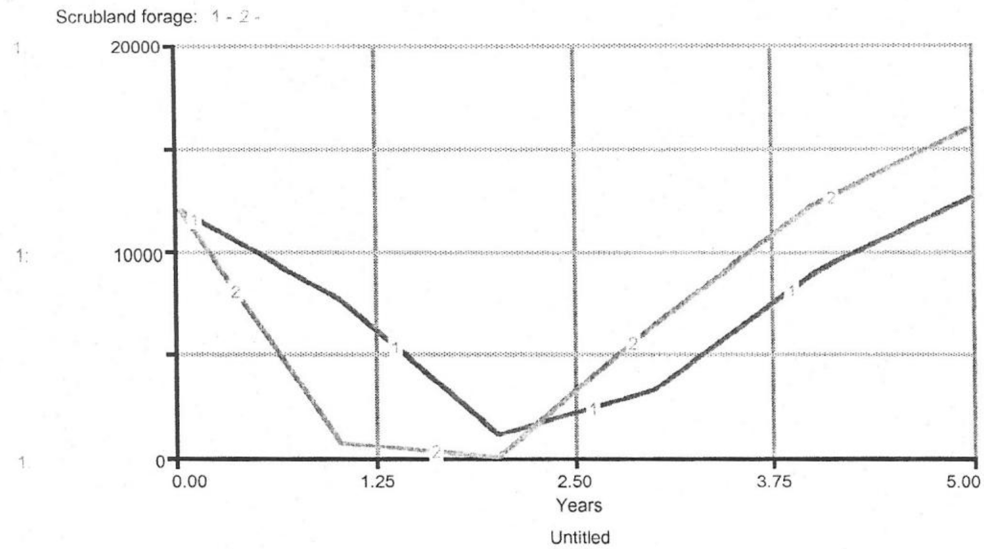

Figure 10. Total sustained revenues and total sustained cost curves for cochineal collection in Ayacucho. Current effort level corresponds to 22 days.

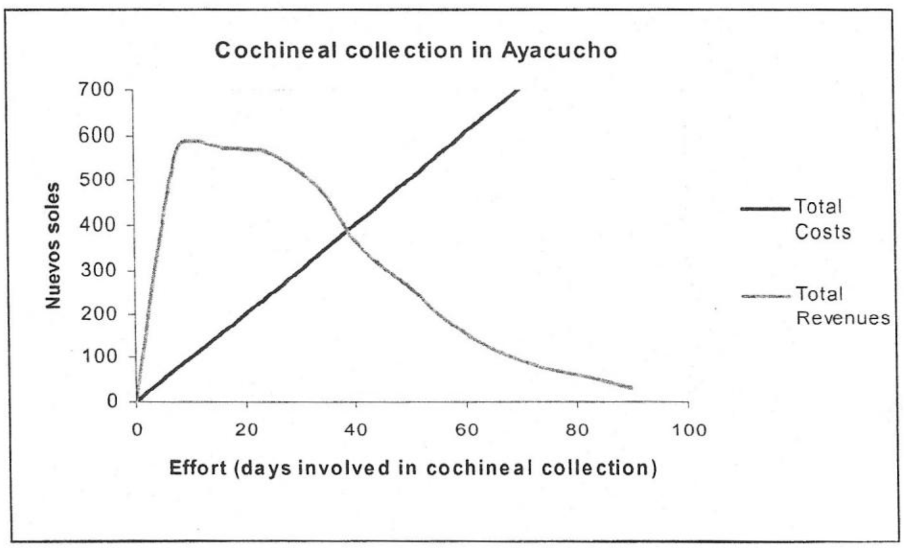

Figure 11. Changes in net present value (NPV), for the range of available values of social capital and labor parameters. The NPV is presented in Nuevos Soles.

Figure 11 a

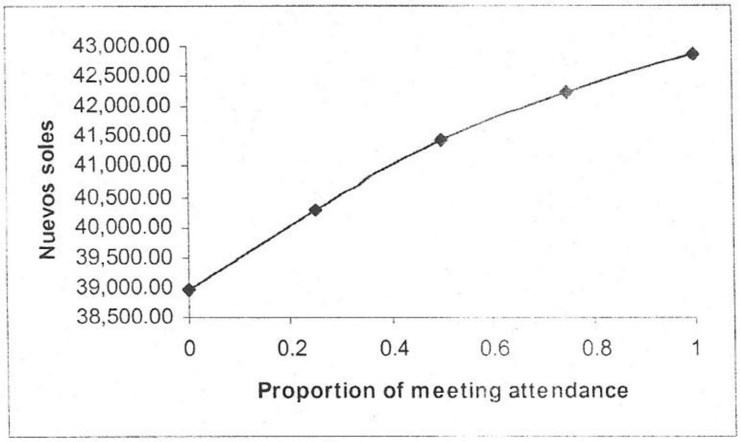

Figure 11 b

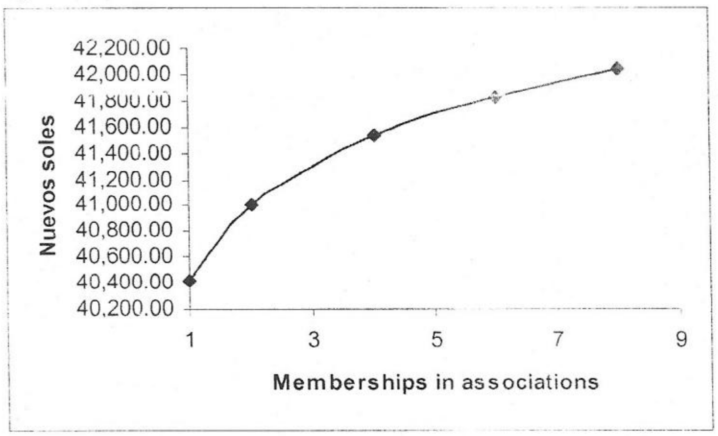

Figure 11c

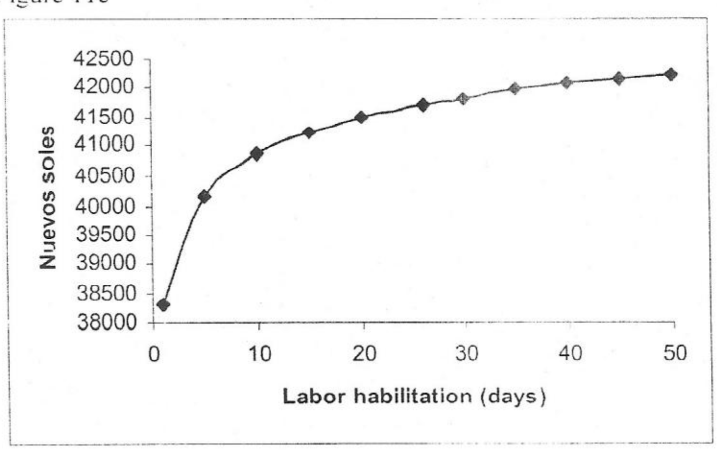

Table 1. Comparison of the output of the calibrated model and the data set.

Variable	Units	Model Output	Data set	
			Average	Std. Dev.
Habilitated Opuntia Scrubland	Hectares	0.97	0.95	0.72
Total Fruit harvested	Kilograms	961	954	596
High quality fruit	Kilograms	633	628	466
Low quality fruit	Kilograms	328	325	266.
Cochineal collected	Kilograms	65.1	63.8	37.2

Table 2. Sensitivity analysis for 5-year simulation run. NPV values are expressed in Nuevos Soles.

	-20%	-10%	INITIAL VALUE	+10%	+20%
Cattle dry matter requirements	2920	3285	3650	4015	4380
NPV	41611	41578	41692	41547	41520
Infestation level	0.24	0.27	0.3	0.33	0.36
NPV	39272	40446	41692	42960	44086
Intermediary traders	0.533	0.6	0.667	0.733	0.8
NPV	54844	48446	41692	34524	26711
Cochineal collection labor	16.8	18.9	21	23.1	25.2
NPV	35099	38472	41692	44762	47689
Fruit harvest labor	4	4.5	5	5.5	6
NPV	41555	41624	41692	41756	41819

Table 3. Sensitivity analysis for 5-years simulation run for social capital parameters and habilitation labor. NPV values are expressed in Nuevos Soles.

	-20%	-10%	INITIAL VALUE	+10%	+20%
Habilitation Labor (days)	20.8	23.4	26	28.6	31.2
NPV	41508	41605	41692	41770	41869
Participation (proportion of meeting attendance)	0.432	0.486	0.54	0.594	0.648
NPV	41472	41583	41692	41798	42030
Membership (number of associations)	4	4.5	5	5.5	6
NPV	41531	41615	41692	41761	41820

Appendix A.

Initial values for parameters and variables used in the model.

Parameter or variable	Value	Units	Source
Age of the head of the household	40	Years	Fieldwork in Ayacucho
Cattle for stocking	1	Tropical Livestock Units	Fieldwork in Ayacucho, Estimated based on Boudet 1975, Pieri 1989
Cattle for sale	2	Tropical Livestock Units	Fieldwork in Ayacucho. Estimated based on Boudet 1975, Pieri 1989
Cattle cost	298	Nuevos soles	Fieldwork in Ayacucho
Cattle dry matter requirements	3650	Kg/ year	Guevara et al. 1996[a]
Cattle price for sell	541.5	Nuevos soles	Fieldwork in Ayacucho
Proportion of cattle benefits invested in buy new cattle	0.58	Dimensionless	Fieldwork in Ayacucho
Initial cochineal stock at the initial available area	940	Kg/ year	Fieldwork in Ayacucho
Cochineal catchability coefficient	0.033	Dimensionless	Fieldwork in Ayacucho
Intermediary traders proportion	0.666	Dimensionless	Fieldwork in Ayacucho
Labor cochineal collection	21	Days/ year	Fieldwork in Ayacucho
Cochineal infestation level	0.3	Surface of the plant infested with cochineal	Fieldwork in Ayacucho
Opuntia plant density	1300	Plants/hectare	Fieldwork in Ayacucho
Intrinsec growth of rate cochineal	0.055	Individuals per individual per unit time.	Mendez Gallegos 1993
Local wage_rate	10	Nuevos soles/ day	Fieldwork in Ayacucho
Initial ammount of harvested fruit	0	Kg/ year	Fieldwork in Ayacucho
Initial fruit stock	250	Units of 20 Kg/year	Fieldwork in Ayacucho
Coefficient of area for fruit harves	0.153	Dimensionless	Fieldwork in Ayacucho
Coefficient of labor for fruit harvest	0.727	Units of 20 Kg/year	Fieldwork in Ayacucho
Available amount of fruit	5000	Kg/ hectare	
Labor fruit harvest	5	Days	Fieldwork in Ayacucho
Price of High Quality Fruit	7	Nuevos soles/ carga	Fieldwork in Ayacucho
Price Low Quality Fruit	4.5	Nuevos soles/ carga	Fieldwork in Ayacucho
Fruit quality ratio	0.65	Dimensionless	Fieldwork in Ayacucho
Initial Opuntia scrubland area	5	Hectares	Fieldwork in Ayacucho
Initial habilitated Opuntia scrubland area	0	Hectares	Fieldwork in Ayacucho
Agricultural income	1562	Nuevos soles/ year	Fieldwork in Ayacucho
Number of asociation that the household is affiliated	5	Dimensionless	Fieldwork in Ayacucho
Scrubland habilitation coefficient for age	0.089	Dimensionless	Fieldwork in Ayacucho
Scrubland habilitation coefficient for agricultural income	0.058	Dimensionless	Fieldwork in Ayacucho
Scrubland habilitation coefficient for labor	0.16	Dimensionless	Fieldwork in Ayacucho
Scrubland habilitation coefficient for outfarm income	0.07	Dimensionless	Fieldwork in Ayacucho

Scrubland habilitation coefficient for number of asociations	0.14	Dimensionless	Fieldwork in Ayacucho
Scrubland habilitation coefficient for participation in cochineal collectors committee	0.39	Dimensionless	Fieldwork in Ayacucho
Labor habilitation	26	Days/year	Fieldwork in Ayacucho
Outfarm incomes	0.27	Proportion of households	Fieldwork in Ayacucho
Participation rate in cochineal collectors committee activities	0.54	Proportion of meeting attendance /year	Fieldwork in Ayacucho
Initial browse stock	607	Kg DM /hectare	Estimated based on Le Houérou 1989, Guevara et al. 1996a
Initial grass stock	1615	kg DM /hectare	Estimated based on Le Houérou and Hoste 1977, Guevara et al. 1996[a]
Initial Opuntia stock	9100	kg DM /hectare	Estimated based on Guevara et al. 1996a, Guevara et al. 1999
Browse availability for cattle	0.5	Dimensionless	Le Houérou 1993
Opuntia carrying_capacity	17000	Kg DM / hectare/ year	Guevara et al. 2003
Opuntia availability for cattle	0.3	Dimensionless	Fieldwork in Ayacucho
Grass availability for cattle	0.8	Dimensionless	Fieldwork in Ayacucho, Guevara et al 1996a
Mean annual rainfall	759	mm /year	Estación Tambillo Huamanga
Rainfall dependency factor	0.8	Dimensionless	Le Houérou 1988, Guevara et al. 1996a
Rain Use Efficiency Browse	1	Kg Dm/ ha /year/ mm	Le Houérou 1989
Rain Use Efficiency Grass	2.66	Kg Dm/ ha /year/ mm	Le Houérou and Hoste 1977
Rain Use Efficiency Opuntia	15	Kg Dm/ ha/ year/ mm	Guevara et al. 1999
Discount rate	0.10		Fieldwork in Ayacucho

IV) DISCUSIÓN GENERAL

El estudio del dominio cultural de la *Opuntia* en comunidades de Ayacucho, permitió la identificación local de los bienes y servicios brindados por los tunales y establecer su interrelación con los componentes de otros sistemas ecológicos y económicos existentes en el área. Adicionalmente, el análisis sugiere que el conjunto de los bienes y servicios reconocidos por los usuarios es un concepto dinámico que puede ser influenciado por factores e instituciones externas a las comunidades.

El capital natural crítico (CNC), es un concepto controvertido en cuanto al alcance de sus diferentes definiciones, pero no en el sentido de las mismas pues básicamente el CNC se refiere a una parte del ambiente natural que provee a los seres humanos de funciones importantes e irremplazables. La determinación de su nivel crítico depende de criterios ecológicos, económicos, políticos y sociales que establecen su importancia para un grupo humano en particular (cf. De Groot et al. 2003). El dominio cultural y el capital natural crítico (sensu Chiesura y de Groot 2003) exhiben muchas características en común, pues dado que ambos tienen un carácter dinámico y multidimensional, la percepción de la importancia de los elementos del dominio, así como las funciones involucradas (i.e. regulación, producción, hábitat e información) pueden cambiar y su importancia relativa verse afectada debido a la existencia de bienes sustitutos, o al estado del conocimiento de los usuarios.

En este sentido, la tesis resalta el papel de los tunales como parte del capital natural disponible en las comunidades locales, mostrando la interrelación de los elementos del dominio cultural de la *Opuntia* con estrategias tales como mejoramiento de suelos y protección de cultivos, las cuales usualmente tienen como objetivo mantener los activos y la capacidad de los hogares para generar ingresos futuros y evitar la vulnerabilidad social (e.g. Watts y Bohle 1993).

El papel de las agencias externas en la modificación del conocimiento de los usuarios respecto a los bienes y servicios provistos por los sistemas naturales es evidente en los tunales de Ayacucho. Algunos bienes o usos de los tunales fueron enunciados como elementos del dominio cultural aunque no son utilizados por los campesinos, siendo resultado de actividades de extensión realizadas por ONGs destinadas a promover la tuna y la cochinilla. Estas organizaciones externas son igualmente importantes en la construcción de capital social *de puente*, y en el establecimiento de relaciones de cooperación económica, asistencia técnica y promoción de nuevos mercados para productos que cuenten con ventajas comparativas (cf. Bebbington 1997). Una parte del capital social existente en las comunidades de Ayacucho es originalmente inducido por agencias externas mediante la creación de asociaciones o grupos relacionados con los proyectos en ejecución. Este fenómeno concuerda con las ideas de Bebbington (1997), respecto a que la formación de capital social puede ser inducida externamente (e.g. Bebbington y Carroll 2002, Healy 2002), y que las asociaciones o relaciones así iniciadas pueden llegar a constituir formas efectivas de capital social (Paldam 2000). Sin embargo, el nivel de organización comunal presente en Ayacucho, la tradición andina de reciprocidad y trabajo comunal, y la evidencia de externalidades positivas consecuencia de la interacción social (sensu Collier 2002), i.e. la capacidad de los campesinos para establecer acciones colectivas, sugieren que el nivel de capital social ya existente en las comunidades de Ayacucho es elevado. Ello fue en su momento puesto de manifiesto con la creación de las rondas campesinas de autodefensa como una muestra de la capacidad extraordinaria de las comunidades para promover acciones colectivas y sobrellevar el impacto de 12 años de violencia derivada de las acciones de Sendero Luminoso, del narcotráfico o del ejercito peruano.

La capacidad de las comunidades para sobreponerse a factores externos y perturbaciones resultado de cambios sociales, políticos o ambientales, resalta su nivel de resilencia social y de capital social, y su habilidad para evitar la ruptura de los nexos entre los sistemas naturales y sociales (cf. Adger 2000). Estas relaciones son más evidentes en el caso de los socio-ecosistemas como los tunales naturales de Ayacucho, pues cambios en la provisión de bienes y servicios por parte del sistema natural podrían exponer a grupos de personas a perturbaciones en sus estilos de vida y a vulnerabilidad social. Por otro lado, la disminución en el papel de las instituciones comunales podría generar una decreciente atención en la definición de los usuarios, el monitoreo de los recursos y la capacidad de los sistemas naturales para recobrarse de las perturbaciones. Es sabido que los sistemas sociales y ecológicos poseen mecanismos que previenen estas situaciones (e.g. Folke et al. 1998, Gunderson y Holling 2002), y que un paso crucial en el estudio de los socio-ecosistemas, además de la identificación de los servicios ecosistémicos claves y su uso por las poblaciones locales, es el investigar el valor asignado a dichos servicios.

El concepto de valor tiene un amplio rango de significados en diferentes disciplinas. Desde una perspectiva ecocéntrica o intrínseca, el valor de una acción u objeto es medido de acuerdo a su contribución para mantener la salud e integridad de un ecosistema o especie, *per se*, independientemente de la satisfacción humana. Por otro lado, los valores instrumentales, e.g. valor económico, son de carácter antropocéntrico y reflejan la contribución de una acción u objeto a la satisfacción de las preferencias humanas de acuerdo a un conjunto de preceptos y condiciones morales que guían los juicios y acciones de los individuos (cf. Farber et al. 2002).

Dado que las preferencias por bienes y servicios ecosistémicos no son fijas, es esperable que los valores instrumentales sean modificables (e.g. Kreuter et al. 2001, Noronha et al. 2002). Esta tesis estudia el efecto de la migración temporal sobre la valoración de los servicios ecosistémicos derivados de la función de regulación, i.e. control de erosión. La migración es un elemento de la dinámica poblacional con diferentes impactos sobre el ambiente y la sociedad. Los resultados muestran poca evidencia de la existencia de un proceso de descontextualización ante la naturaleza (sensu Giddens 1991, Borgström y Wackernagel 1999) por parte de los campesinos migrantes y contrariamente, apoyan las ideas de Locke et al. (2000) que sugieren que la migración circular puede incrementar la resilencia social de los hogares, diversificando los estilos de vida de los campesinos y promoviendo la inversión en recursos y activos.

Aunque mayormente la migración humana ha sido asociada con pérdida de resilencia social y vulnerabilidad, esas generalidades no son siempre exactas. En el caso de poblaciones que han sido siempre móviles, en las que la migración es parte de las estrategias de los hogares, e.g. las poblaciones rurales andinas, la migración puede tener impactos positivos sobre la resilencia de las sociedades al incrementar el capital social y humano (Hartmann 1998). Es por lo tanto necesario para la comprensión de los impactos ambientales y sociales de la migración en Ayacucho, establecer la diferencia entre migración temporal y desplazamiento poblacional.

Este último término se refiere al abandono obligado de los lugares habituales de residencia como resultado de, o para evitar, los efectos de conflictos armados, violencia generalizada, desastres naturales o desastres causados por el hombre (Cohen 1998). Las poblaciones desplazadas están generalmente física, económica, social y culturalmente aisladas de su ambiente, lo cual genera consecuencias en el largo plazo, e.g. disfuncionalidad de las instituciones locales, alteración de las formas tradicionales de manejo de recursos y pérdida de conocimiento tradicional (Locke et al. 2000, Stepputat y Sørensen 2001). En Ayacucho, se estima que el número de desplazados como consecuencia de los años de violencia fue *ca.* 150,000 personas (SEPIA 1997). Aunque esta tesis no se focalizó en la valoración de los servicios ecosistémicos por parte de individuos desplazados, su gran número y la existencia potencial a largo plazo de efectos negativos sobre el ambiente y la sociedad, resaltan la necesidad del estudio del perfil histórico del socio-ecosistema para la comprensión de su resilencia y dinámica (e.g. Walker et al. 2002).

A lo largo de esta tesis se ha optado por una aproximación transdisciplinaria a los problemas planteados, aunque intentando mantener un equilibrio entre la ciencia normal (sensu Kuhn 1970), en la que mayormente se relegan o ignoran los temas sociales y éticos dentro de las diversas disciplinas, y la ciencia post-normal o modo-2 (Gibbons et al. 1994), en la que la pronunciada transdisciplinaridad no permite el desarrollo de formalismos y rigor. Esta búsqueda de equilibrio es una preocupación actual dentro de la economía ecológica y otras ciencias transdisciplinarias focalizadas en la generación de conocimiento en un contexto aplicado (cf. Müller 2003). En ese sentido, el desarrollo de esta tesis ha permitido identificar y valorar los servicios ecosistémicos provistos por los tunales, así como establecer el papel del capital social en el cambio en el uso del suelo y generar un modelo que permite comprender la dinámica del socio-ecosistema y la sensibilidad del mismo a un amplio rango de parámetros biológicos, sociales y económicos, lo cual podría ser empleado para la formulación de políticas destinadas a elevar el nivel de vida de los campesinos.

El reconocimiento por parte de la ecología que el hombre es una especie clave que cambia la estabilidad del sistema alterando las restricciones ambientales, la tasa de los procesos y las estructuras bióticas está presente en este trabajo. Tal como menciona O'Neill (2001), el impacto del hombre no esta limitado a la cantidad de bienes y servicios que extrae del ecosistema. El impacto a largo plazo estará determinado por la manera en que esta extracción altera su estabilidad. Los ejemplos de pérdida de estabilidad son abundantes y van desde la desestabilización de arrecifes de coral (Hughes 1994), la desestabilizacion de sabanas semi aridas por sobrepastoreo (Loehle 1985) o su conversión en desierto (Hills 1966), hasta cambios en el uso del suelo que generan perdida de estabilidad en los sistemas naturales, y una mayor tasa de erosión (Kahn 1995).

Sin embargo, el concepto de estabilidad es dependiente de la escala espacial de observación y el balance entre la distribución de las perturbaciones y la capacidad efectiva de dispersión de la biota. Si se considera como ecosistema una región muy amplia, entonces unicamente grandes perturbaciones, las cuales ocurren con poca frecuencia, podrán afectar su estabilidad. Contrariamente si se considera como ecosistema una pequeña área entonces la posibilidad que un evento desestabilizador ocurra, aumenta proporcionalmente. La capacidad de dispersión de la biota esta a su vez definida por las limitantes ambientales bióticas y abióticas de cada especie, las barreras de dispersión y los mecanismos de dispersión de cada especie. El ser humano es capaz de alterar las estructuras de los sistemas ecológicos y crear barreras que impiden la dispersión de las especies, así como introducir poblaciones y favorecer su dispersión. Un ejemplo de ello es la introducción de diversas especies de *Opuntia* a Australia y Sudáfrica por parte de marinos Británicos, con la intención de establecer colonias de cochinilla. Una vez en dichos lugares, las plantas de *Opuntia* se convirtieron en plaga, expandiéndose por gran parte de esos paises hasta su control biológico por parte de *Cactoblastis cactorum* lo cual permitió que esas tierras sean convertidas en pastizales (Mann 1969).

En el caso de los tunales y la cochinilla en las comunidades campesinas estudiadas, no es la extracción de cochinilla *per se* lo que podría generar desestabilización en el sistema sino el cambio en la cobertura vegetal consecuencia de la habilitación de los tunales para la recolección de cochinilla. Esta habilitación podría generar cambios en la frecuencia de eventos capaces de desestabilizar el sistema, pues al ser alteradas sus estructuras i.e. disminuir la cobertura vegetal debido a la poda, raleo y limpieza del terreno, disminuye la capacidad del tunal para retener el suelo y evitar deslizamientos de tierra durante la temporada de lluvias. Este tipo de perturbaciones consecuencia de la disminución de cobertura vegetal, esta bastante descrita en los Andes de Perú (e.g., Alfaro y Cárdenas 1988). A pesar que la cochinilla es una especie cuyos estadíos adultos son sésiles y los estadíos ninfales tienen una capacidad de dispersión muy limitada (Flores y Tekelemburg 1995), la conjunción de factores biológicos i.e. existencia de áreas de refugio en los tunales, factores humanos i.e. la capacidad de los campesinos para realizar infestaciones artificiales y factores económicos i.e. los bajos precios de la cochinilla, permiten mantener los niveles poblacionales del insecto. Sin embargo, es sabido que en condiciones de precio favorables la contribución relativa de esos factores puede verse alterada y extinciones locales de las poblaciones de insecto han ocurrido, especialmente cuando los precios elevados de la cochinilla, coinciden con la temporada de lluvia durante la cual la supervivencia de los estadíos ninfales es menor y la posibilidad de colonizar nuevas plantas es muy baja.

No obstante la capacidad de recobrar los niveles poblacionales de cochinilla, y la recuperación de la cobertura vegetal luego de la habilitación, el sistema puede no estar recuperado. Desde una perspectiva ecosistémica en que las variables de estado sean grupos funcionales y no se consideren las diversas especies que realizan la función o proveen el servicio, la recuperación de la cobertura vegetal podría permitir que se incremente la capacidad del sistema para retener suelos y disminuir la erosión aunque luego de la perturbación la mayor parte de la cobertura vegetal sea provista por otras especies y la *Opuntia* sea desplazada como especie dominante. Otros bienes y servicios provistos por el sistema pueden no recuperarse puesto que su provisión depende en gran medida de la distribución y abundancia de algunas especies. Así, si disminuye o desaparece la población de *Opuntia*, disminuirá también la capacidad del sistema para brindar frutas y cochinilla, lo cual puede tener efectos negativos sobre la sociedad (cf. Middleton 1999). Esto no significa que el ecosistema deba necesariamente ser definido por las especies existentes y que no exista cierta capacidad de sustitución entre ellas, pero la comprensión del papel de la diversidad biológica y la diversidad de grupos funcionales sobre distintas propiedades de los sistemas naturales es todavía bastante pobre (e.g., Bengtsson et al. 2003).

Ayacucho es uno de los lugares de Perú donde existe menos información respeto a la diversidad biológica, su uso y estado de conservación. El análisis de la información disponible ha resaltado la importancia de los tunales naturales para la conservación de la flora y fauna asociadas a ellos (Torres 2001). Sin embargo estudios específicos sobre la diversidad biológica existente en esos sistemas naturales aún estan por realizarse.

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ANEXO

El propósito de estas preguntas es comprender como trabaja la tierra, los tunales y como funciona su comunidad. Su participación es importante, pero no tiene la obligación de responder si es que no lo desea. Agradezco su colaboración y tenga la certeza que los datos que proporciona serán confidenciales.

DATOS GENERALES

Fecha:_________________
Comunidad: __________________________
Nombre y Apellido:____

MIEMBROS DEL HOGAR

Nombre	Parentezco	Edad	Sexo	Ocupación	Instrucción

CULTIVOS EN LA FINCA ENTERA (BAJO MANEJO DEL HOGAR)

Cultivo	Nro total Parcelas	Extensión	Rotación	Riego	Producción aproximada	Precio/Kg

INSUMOS PARA LOS CULTIVOS

INSUMO	Nombre	Cantidad	Unidad	Kg/unidad	Costo total
ABONOS					
FERTILIZANTES QUIMICOS					
PLAGUICIDAS					
OTROS					

CULTIVOS: JORNALES CONTRATADOS

ACTIVIDAD	TRACTOR HORAS	COSTO HORA	YUNTA DIAS	COSTO DIA	JORNALES	COSTO JORNAL
BARBECHO						
SIEMBRA						
APORQUE						
CONTROL SANITARIO						
COSECHA						
OTROS						

Compró o vendió Ud.un terreno en los últimos dos años? ________________

Descripción:	Area	Precio
Terreno de cultivos______________	_______	_______
Terreno de pastos______________	_______	_______
Otro______________________	_______	_______

CULTIVOS COMUNALES: Contribución mano de obra familiar

ACTIVIDAD	Jornales
BARBECHO	
SIEMBRA	
APORQUE	
CONTROL SANITARIO	
COSECHA	
OTROS	

PRODUCCIÓN APROXIMADA QUE BENEFICIA AL HOGAR

CULTIVO	Cantidad	Unidad	Kg/unidad	Total Kg,

GANADO: Se refiere al número de cabeza al final de la temporada de lluvias.

Especie	Nro Cabezas	Ventas	Precio venta	Auto consumo	Muertos	Nacidos	Compras	Precio compra

PRODUCTOS GANADEROS

Lana — Animales esquilados ________ Cantidad de lana ________ Precio ____

Leche — Número de animales ________ Meses ordeño ________ Litros/día ________ Precio ________

PASTOS Y FORRAJES BAJO MANEJO DEL HOGAR

Lugar de pastoreo	Area	Número de animales	Posición y temporada de uso	Tiene Opuntia

PASTOS COMUNALES

Lugar de pastoreo	Area	Número de animales	Posición y temporada de uso	Tiene Opuntia

ACTIVIDADES FUERA DEL PREDIO
MIGRACION

Nombre	Destino	Actividad	Epoca mes del año	Tiempo consagrado	Salario jornal	Costos estimados	Remesas

OTRAS ACTIVIDADES FUERA DEL PREDIO SIN MIGRAR

Nombre	Actividad	Epoca mes del año	Tiempo consagrado	Salario jornal	Costos estimados	Ingreso

HABILITACION TUNALES

Superficie	Poda	Caminos	Traslado desmonte	Remosion	Cercado	Deshierbo	Densidad tunal

RECOLECCIÓN DE RECURSOS DEL TUNAL

	Unidad de medida	Cantidad por vez	Número de días cosecha	Precio
Tuna 1				
Tuna 2				
Cochinilla				
Leña				
Pdtos adorno				
Otros				

Realiza usted infestaciones artificiales______________
Superficie infestada___________
Cantidad de cochinilla usada en la infestación________
Rendimiento____________

¿Cómo vende usted su cochinilla? ¿Cómo la seca? ¿A quien se la vende?

¿Ha recibido dinero adelantado para recoger cochinilla, ¿de quien? ¿Qué precio tenía?

¿Puede usted nombrar los usos o cosas buenas que le brindan los tunales, para que sirven?

¿Conocía Ud todos esos usos, cómo supo de algunos de ellos, los usa regularmente?

¿Pertenece Ud a algún comité de recolectores de cochinilla?

¿Asiste regularmente a las reuniones? ¿Cuántas se ha perdido? ¿Es lider del comité?

¿A cuantas otras asociaciones o *con que oficinas* trabajan los miembros de su casa, algún miembro de su familia es dirigente de alguna de ellas?

¿Cúales son las asociaciones más importantes, por que?

¿Esas asociaciones son de la comunidad o vienen de gente de afuera?

___

¿Cualquiera puede ingresar a esas asociaciones, cómo se entra, quiénes las conforman?

___

¿Considera que sus suelos son más productivos o igual de productivos que hace 10 años?

___

¿Percibe Ud. algún cambio en la profundidad de los suelos en los últimos años?

___

Los tunales protegen los suelos contra la erosión, evitando la perdida de suelo y mejorando la capacidad de la tierra para absorber agua. Es sabido que algunas instituciones estarían promoviendo prácticas de manejo que impedirían que tu disfrutes de esos beneficios en tus terrenos. Teniendo en cuenta la cantidad de plata que tienes y lo que puedes gastar en otras cosas, ¿estarías dispuesto a pagar _______ a la comunidad cada mes, a fin de mantener esos beneficios?

GRACIAS POR SU COOPERACIÓN Y LA AYUDA QUE ME HA BRINDADO AL RESPONDER ESTAS PREGUNTAS.