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A socio-ecological Analysis

Thomas Kastner

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Institute of Social Ecology
IFF - Faculty for Interdisciplinary Studies (Klagenfurt, Graz, Vienna)
Klagenfurt University
Schottenfeldgasse 29
A-1070 Vienna
+43-(0)1-522 40 00-401
www.iff.ac.at/socec
iff.socec@uni-klu.ac.at

Human appropriation of net primary production (HANPP) in the Philippines 1910-2003: a socio-ecological analysis

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Verfasser:	Thomas Kastner
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Betreuer:	Ao. Univ.-Prof. Dr. Helmut Haberl

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Foreword

This working paper is basically identical with my thesis, which was created over a period of about two years from the first ideas on the topic in February 2005 to the finalization of this written document in February 2007. Starting from my general interest in how natural systems and human societies interact, I found an interesting and challenging surrounding at the Institute of Social Ecology in Vienna, where interdisciplinary approaches are used to tackle questions of society-nature relations. The topic of my research was established and developed in talks with my promoter Helmut Haberl. I spent five months at the University of the Philippines in Los Baños (UPLB) from October 2005 to March 2006. This stay was a valuable experience. I was able to attain valuable information and data for my study, and was introduced to various realities and beauties of the Philippines. Back in Austria, my research gained shape through numerous discussions with the people at the Institute of Social Ecology.

This work would not have been possible without the support of many. My gratitude belongs to:

- my promoter Helmut Haberl, Karlheinz Erb and Fridolin Krausmann at the Institute of Social Ecology for guiding me through the process of establishing this thesis, for their support and the fruitful discussions;
- Annabella and Elmar, my fellow “HANPPies” who helped me a lot through frequent discussions and exchange of information; Annabella deserves a special mention for proof-reading this thesis and helping me with my English;
- the KWA-scholarship programme of the University of Vienna, the Julius-Raab Stiftung and the Studienbeihilfenbehörde for financially supporting my research stay at the UPLB;

- Marc who provided me with valuable information on life in the Philippines and Los Baños and established the contact to the UPLB through his former supervisor;
- Damasa M. Macandog who hosted me at the UPLB and made my stay both pleasant and successful; she introduced me to a number of experts, helped me in gathering data and knowledge and provided me with a working space in her office; there I found friends in Edwin, Girlie, Levi and Rick who supported me in my work and taught me about life in Los Baños;
- Philippine scientists who shared their knowledge and provided me with publications and data. These include: Rodel Lasco, Roberto Visco, Lucila Lapar, Leovina Tandug, Arnold Olave, Alma Arquero and Pinky Tassara;
- many who helped me and of whom I often do not even know the names, such as the helpful library staff at IRRI and at PCARRD;
- all my friends, who gave me backing to keep my spirits high through the process of my thesis and throughout my whole studies; I do not have to mention names here; those concerned will know, should they ever bother to read this;
- Lea, who shares my feelings and was always there for me over the past two years; and finally,
- all my family for supporting me throughout my studies and distracting me when necessary.

The photos used to frame the different chapters were taken during my research stay in the Philippines. An appendix, consisting main input data, major results and factors used, accompanies the hardcopy of my thesis in digital form on CD. Spreadsheets and further information can be obtained from the author; please send an inquiry to thomas.kastner@gmx.at.

Vienna, February 2007,

Thomas Kastner

Contents

Abstract

Human land use practices alter ecosystem energy flows to a significant degree. This work uses the “Human Appropriation of Net Primary production” (HANPP) as an aggregate measure to quantify this human dominance over nature. The system under investigation are the Philippines on national level, the timeframe is set from 1910 to 2003. This study provides the first long term time series of HANPP for a tropical developing country with a colonial history. Available statistical data and simple model assumptions are used to generate a continuous assessment of HANPP and its subcomponents which include human biomass harvest. This makes it possible to trace fundamental changes in human land use practices, in socio-economic biomass metabolism and in agricultural productivity.

The results show a two-fold increase in HANPP over the period observed. The human population of the Philippines increased 10-fold within the same timespan. Drastic changes in human biomass use had to occur to maintain biomass supply for basic human needs, such as food, feed, and fuel. Over the last decades HANPP was continuously high; significantly over 50%. Less than half of the potential ecosystem productivity remained in the system to be used by other organisms. The observed changes in societal biomass metabolism include an aerial expansion of permanent agriculture in a first phase and the shift to “modernized” intensified agriculture in a second phase. While the first phase was related to strong increases in HANPP, the second phase, which started in the 1960s with the so-called “Green Revolution”, was characterized by increased biomass harvest through rising per area yields. The latter process contributed to a stabilization of HANPP, which was achieved through high external, fossil fuel depended inputs and linked to environmental costs, such as eutrophication and contamination through pesticides. Other developments that illustrate high human pressure on nature include the overexploitation of forest resources, which led to a peak in wood production in the early 1970s and a drastic decline since then; migration flows from regions with deteriorated or overused natural resources; the change to a negative physical biomass trade balance in the 1980s. Consequently, the results of the presented research suggest that the nation might be at its biophysical limits in relation to a number of aspects.

Deutsche Kurzfassung

Die vorliegende Arbeit beschäftigt sich mit Gesellschafts-Natur-Beziehungen im Allgemeinen und mit dem menschlichen Einfluss auf ökosystemare Flüsse im Speziellen. Nettoprimärproduktion (NPP) ist die Menge Kohlenstoff, der von autotrophen Organismen (vor allem grünen Pflanzen) innerhalb einer definierten Zeitspanne assimiliert wird. Sie stellt damit die Energiebasis für heterotrophes Leben dar. Anthropogene Landnutzung verändert natürliche NPP-Flüsse signifikant. Um die menschliche Dominanz zu quantifizieren, wird in dieser Arbeit das Konzept der menschlichen Aneignung von NPP (HANPP) verwendet. Dabei werden zwei Prozesse berücksichtigt: i) Verminderung der natürlichen Produktivität durch Landnutzungsänderungen (ΔNPP_{LC}) und ii) NPP-Entnahme durch die Ernte von Biomasse (NPP_h). Die Studie beschränkt sich aufgrund der Datenlage auf die terrestrische, oberirdische Produktivität (ANPP). Das untersuchte System sind die Philippinen auf nationaler Ebene über den Zeitraum von 1910 bis 2003. Damit stellt die vorliegende Arbeit die erste HANPP-Zeitreihenanalyse für ein tropisches Entwicklungsland dar, die eine derart lange Zeitspanne abdeckt.

Die Philippinen sind ein Inselstaat mit insgesamt über 7000 Inseln, wobei die größten elf 94% der Landesfläche ausmachen. Sie werden zum insularen Südostasien gezählt und liegen zur Gänze in den Tropen. Das Klima ist überwiegend feucht-tropisch mit reichlichen Niederschlägen. Über den betrachteten Zeitraum erlebte das Land eine Bevölkerungsexplosion um den Faktor zehn, von 8,2 Millionen 1910 auf 82 Million 2003.

Zur Berechnung der HANPP war die Erhebung folgender Items in Zeitserien notwendig:

- ein Landnutzungsdatensatz;
- die Produktivität der potentiellen Vegetation;
- die Produktivität der aktuellen Vegetation;
- die geerntete Biomasse; dabei wurden folgende Prozesse berücksichtigt:
    - die Ernte von landwirtschaftlichen Produkten, inklusive anfallender Nebenprodukte;
    - die von Nutztieren geweidete Biomasse;

- die Holzernte, inklusive im Wald verbleibender, bei der Ernte getöteter Biomasse.
- die durch vom Menschen verursachte Feuer verbrannte Biomasse;

Bei der Erstellung der Zeitreihen-Datensätze wurde zunächst auf statistische Daten zurückgegriffen. Wo dies nicht möglich war, wurden Entwicklungen mit einfachen Modellannahmen rekonstruiert. Als besonderes Problem stellte sich das Erstellen eines konsistenten Landnutzungsdatensatzes heraus, da hier die Daten oft lückenhaft und unzuverlässig waren. Letztendlich konnte ein „best-guess“ gefunden werden, mit dem es möglich war, die für die Arbeit wichtige Produktivität der jeweils aktuellen Vegetation abzubilden. Für die Biomasseernte wurden in großem Umfang historische Quellen gesichtet. Für die von Menschen verursachten Feuer konnten nur sehr grobe Schätzungen gefunden werden, obwohl Wanderfeldbau und Brandrohdungswirtschaft, vor allem historisch, auf den Philippinen eine bedeutende Rolle spielen. Dadurch wurde die so verbrannte Biomasse nicht zur Gänze in die Zeitreihe integriert, sondern konnte lediglich als zusätzliche grobe Abschätzung präsentiert werden. Für diese Abschätzung diente ein einfaches Modell, das auf Biomassebeständen pro Fläche und so genannten „combustions factors“ (d.h. dem Anteil der bei Feuer verbrannten Biomasse an der Gesamtbiomasse) basiert.

Die Ergebnisse der Arbeit zeigen einen deutlichen Anstieg der HANPP über den betrachteten Zeitraum, von unter durchschnittlich 3 Tonnen Trockenmasse pro Hektar und Jahr (t DM/ha/a) am Anfang der Zeitserie auf über 6,5 t DM/ha/a an deren Ende. Die natürliche oberirdische Produktivität des Landes liegt ca. 11,7 t DM/ha/a. Bei Berücksichtigung der durch Brandrohdungswirtschaft verbrannten Biomasse tritt noch immer fast eine Verdoppelung der HANPP über den Verlauf des 20ten Jahrhunderts auf. In den letzten Dekaden liegt die HANPP über 50%, das heißt weniger als die Hälfte der natürlichen oberirdischen Produktivität verbleibt in den Ökosystemen. Bei solch hoher menschlicher Dominanz über natürliche Systeme sind drastische Auswirkung auf die Biodiversität zu erwarten. In der Tat weisen die Philippinen einen sehr hohen Biodiversitätsverlust auf, das Herstellen eines direkten Zusammenhangs mit der Entwicklung der HANPP war allerdings im Rahmen dieser Arbeit unmöglich.

Betrachtet man die Entwicklung der HANPP über die Zeit, so wird ein kontinuierlicher Anstieg von Anfang des 20ten Jahrhunderts bis ca. Ende der 1960er, und eine deutliche Verlangsamung dieses Anstiegs ab diesem Zeitpunkt, offensichtlich. Die anfangs stetige Zunahme der HANPP liegt vor allem in der flächenmäßigen Expansion der permanenten Landwirtschaft und der damit in Verbindung stehenden Entwaldung des Landes begründet. Dabei wurde die Landwirtschaft größtenteils ohne größere externe Inputs betrieben und die Produktivität pro Fläche war typischerweise niedrig (hohe $\Delta ANPP_{LC}$). Weiters dehnte sich, wohl v.a. auf aufgelassenen landwirtschaftlichen Nutzflächen, Sekundärvegetation wie Gras- und Buschländer aus, die eine niedrigere ANPP als die natürlichen Wälder aufweisen. Dabei sind v.a. von der Spezies *Imperata cylindica* dominierte Grasländer hervorzuheben. Diese haben einen sehr geringen wirtschaftlichen Nutzen, können lediglich extensiv beweidet werden und bilden in Südostasien oft Feuer-Klimax-Gesellschaften, die in der Trockenzeit regelmäßig abbrennen. Eine Rehabilitierung dieser *Imperata*-Grasländer zu höher produktiven Flächen gestaltet sich schwierig, vor allem aufgrund ihres ausgedehnten Wurzelwerks. Ein weiterer Grund für den erwähnten Anstieg der HANPP-Werte ist die Steigerung der Industrieholzernte. Zusammenfassend war diese Phase der kontinuierlich steigenden HANPP durch eine deutliche Erhöhung sowohl der „entgangenen“ NPP ($\Delta ANPP_{LC}$) als auch der gesellschaftlich nutzbaren Biomasseernte ($ANPP_h$) gekennzeichnet, wobei die Ausdehnung permanent landwirtschaftlicher Nutzflächen und Flächen menschen-gemachter Sekundärvegetation eine herausragende Rolle spielte.

Für die Verlangsamung des Wachstums der HANPP mit ab Ende der 1960er können zweierlei Hauptgründe ausgemacht werden:

- Die einsetzende Intensivierung der Landwirtschaft. Als Startpunkt hierfür kann auf den Philippinen die Gründung des Internationalen Reisforschungsinstituts (IRRI) 1960 angesehen werden. Der Schwerpunkt dieser Intensivierung lag eindeutig im Reissektor. Es wurden Reissorten in Umlauf gebracht, die stärker auf anorganische Düngung ansprechen und so höhere Erträge erzielen. Weiters wurden Bewässerungssysteme ausgebaut und damit regelmäßig zwei Reisernten pro Jahr ermöglicht. Somit wurde auf Kosten deutlich gesteigerter externer Energieinputs die Produktivität erhöht (Reduktion von $\Delta ANPP_{LC}$) und damit eine höhere Biomasseernte auf gleich bleibender Fläche ermöglicht. Damit war eine Erhöhung der NPP_h am Ackerland bei einer Stabilisierung der HANPP möglich. Die Expansion des permanent genutzten Ackerlandes verlangsamte sich deutlich, und scheint seit den 1980ern zum Erliegen gekommen zu sein. Allerdings war diese Entwicklung der gesteigerten Produktivität aller Wahrscheinlichkeit nach mit anderen (Umwelt)kosten, wie z.B. Eutrophierung durch starke Stickstoffdüngung, Folgewirkungen von Pestizideinsatz, Verlust von Flexibilität bei unvorhergesehen Ereignissen und vermehrte Abhängigkeit der Bauern von Faktoren außerhalb ihres Einflussbereichs. In den letzten Jahren der Zeitserie erreichte die aktuelle Produktivität am Ackerland beinahe die potentielle. Im internationalen Vergleich sind die Erträge auf den Philippinen dennoch relativ niedrig. Eine weitere Steigerung der Produktivität scheint möglich, allerdings wohl nur, so weitere Steigerungen an externen Inputs und Investitionen in den Ausbau der Infrastruktur (z.B. Bewässerungskanäle) erfolgen.

- Die Ernte von Industrieholz zeigt einen deutlichen Peak Anfang der 1970er und danach einen extremen Einbruch. Es scheint, dass die Holz-Ressourcen des Landes auf extrem unnachhaltige Weise ausgebeutet wurden. In den „Blütejahren“ waren die Philippinen einer der führenden Exporteure von Tropenholz weltweit. Dabei ging der Löwenanteil des gebrachten Industrieholzes unbearbeitet ins Ausland. Durch ein System der Korruption gingen die Profite fast ausschließlich an einige wenige, der Regierung wohl gesonnen Familien der lokalen Elite. Diese erhielten Einschlaglizenzen, die weit über den Mengen lagen, die eine nachhaltige Nutzung der Wälder erlaubt hätten. Eine erfolgreiche Wiederaufforstung fand in großem Rahmen nicht statt. Außerdem waren die durch kommerzielle Operationen geöffneten Wälder oft das Ziel von armen Migranten, die auf der Suche nach Land dort unter unsicheren Besitzverhältnissen Landwirtschaft betrieben. Die Folge war die eingangs erwähnte drastische Entwaldung, die Holzindustrie brach in den 1980ern zusammen und mittlerweile sind die Philippinen Nettoimporteur von Holzprodukten. Der damit verbundene extreme Rückgang der Holzernte war für die Stabilisierung der HANPP in den letzten Dekaden mitverantwortlich.

Es ist interessant zu betrachten, wie sich die Pro-Kopf-Werte der HANPP und der einzelnen Komponenten über die Zeit entwickeln, vor allem im Zusammenhang mit der erwähnten Bevölkerungsexplosion. Die HANPP lag nach meinen Berechungen 1910 bei schon ca. 25% der potentiellen NPP (mit Berücksichtigung der Brandrodungswirtschaft noch höher). Bei einer

Verzehnfachung der Bevölkerung scheint eine lineare Korrelation mit der Entwicklung der HANPP unmöglich, da eine HANPP von 250% über die gesamte Landesfläche wohl kaum möglich bzw. aufrechtzuerhalten wäre. In der Tat geht die HANPP pro Kopf deutlich zurück (von ca. 10 t DM pro Kopf 1910 auf ca. 2,6 t pro Kopf 2000), wobei der Rückgang der $\Delta ANPP_{LC}$ pro Kopf deutlich stärker ist als der der Biomasseernte pro Kopf. Um die gesellschaftlich benötigte Ernte von Biomasse zu gewährleisten, findet also eine Effizienzsteigerung statt, die mit der beschriebenen landwirtschaftlichen Intensivierung in engem Zusammenhang steht. Auch „innerhalb" der Biomasseernte steigt der gesellschaftlich genutzte Anteil relativ stärker als z.B. die ohne direkten Nutzen verbrannte Biomasse. Dennoch scheint durch den extremen Bevölkerungsanstieg einzig die kommerzielle Produktion von pflanzlichen landwirtschaftlichen Produkten den Pro-Kopf-Wert über die Zeit auf konstantem Niveau halten zu können. Alle anderen Pro-Kopf-Werte gehen über die Zeitserie zurück. Dennoch sind die Philippinen fast über den gesamten betrachteten Zeitraum ein Netto-Importeur von Reis, dem wichtigsten Grundnahrungsmittel im Land.

Die Analyse des Handels mit Biomasse zeigt ebenfalls ein interessantes Ergebnis. Traditionell waren die Philippinen, aufgrund ihrer Kolonialgeschichte, ab dem ausgehenden 19ten Jahrhundert Exporteure von Produkten wie Zuckerrohr, Kokosnüssen, Manila-Hanf und Tabak. Die Landwirtschaft war seit diesem Zeitpunkt sehr auf die Exportwirtschaft ausgerichtet, was auch zu den erwähnten Reisimporten beitrug. Bis spät ins 20te Jahrhundert waren die Philippinen ein Netto-Exporteur von relativ großen Mengen an Biomasse; dies verkehrte sich im Verlauf der 1980ern ins Gegenteil, und mittlerweile sind die Netto-Importmengen beträchtlich. Gründe für diese Entwicklung waren ein steigender Inlandsbedarf mit der wachsenden Bevölkerung, die beschriebene Entwicklung im Forstsektor, wirtschaftliche Schwierigkeiten in den 1980ern und die Bindung der Philippinen an GATT und WTO. Man kann also annehmen, dass die Verkehrung der physischen Biomasse-Handelbilanz auch zur erwähnten Stabilisierung der HANPP beitrug, da die konsumierte Biomasse vermehrt aus dem Ausland stammte und weniger exportiert wurde.

Neben den beschriebenen Entwicklungen deutet auch die Tatsache, dass die Philippinen seit den 1970ern eine hohe Emigration aufweisen (zur Zeit befinden sich ca. 10% aller Filipinos im Ausland) darauf hin, dass das biophysische System der Nation mit zunehmendem Bevölkerungsdruck und steigender Umweltdegradation an seine Limits gerät.

Abschließend wäre es interessant zu fragen, ob es so etwas wie typische zeitliche Entwicklungsverläufe der menschlichen Aneignung von NPP gibt. Dazu gibt es leider noch wenig vergleichbare Studien, die auf nationaler Ebene einen längeren Zeitraum abdecken. Eine vorliegende Arbeit für Österreich zeigt dort eine durchaus ähnliche Entwicklung durch die Intensivierung der Landwirtschaft, d.h. hohe externe Inputs und dadurch Stabilisierung der HANPP, bei gleichzeitiger weiterer Steigerung der Biomasseernte durch Reduktion der $\Delta ANPP_{LC}$. Allerdings gibt es im österreichischen Kontext kein vergleichbares Bevölkerungswachstum und die Ausgangslage für die Entwicklung ist natürlich eine gänzlich andere als auf den Philippinen mit ihrer Kolonialgeschichte. In naher Zukunft werden eine Reihe von historischen HANPP Studien veröffentlicht (auf nationaler und globaler Ebene). Ein Vergleich der verschiedenen Entwicklungsverläufe wäre jedenfalls interessant.

Die vorliegende Arbeit zeigt einen Übergang in Mensch-Umwelt Beziehungen in einem tropischen Entwicklungsland, mit kolonialer Vergangenheit und starkem Bevölkerungswachstum. Als erste Phase im betrachteten Zeitraum steht die flächenmäßige Expansion der permanenten Landwirtschaft (wahrscheinlich verbunden mit dem Zurückdrängen des Wanderfeldbaus). Dabei entsteht großräumig Sekundärvegetation auf aufgelassenen Flächen. Die Landwirtschaft findet ohne größere Mengen externer Inputs statt und hat typischerweise relativ niedrige Erträge. Die natürlichen Wälder werden stark zurückgedrängt. Somit steigt die HANPP in dieser Phase schnell an. Die zweite Phase zeichnet sich durch eine Intensivierung der Landwirtschaft aus. Dadurch kann, über hohe externe Inputs und damit verbundenen Umweltkosten, die Produktivität des Ackerlands gesteigert werden. Die Expansion der Landwirtschaft in neue Flächen verlangsamt sich deutlich, wohl auch weil hier die Limits an verfügbarem nutzbarem Land erreicht werden. So ist eine Stabilisierung der HANPP bei weiter wachsenden Biomassenernten möglich. Diese Stabilisierung tritt allerdings, wohl auch aufgrund des starken Bevölkerungsdrucks, auf einem sehr hohen Level der HANPP ein.

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Abbreviations used

ANPP	aboveground NPP
$ANPP_0$	ANPP of the potential vegetation
$ANPP_{act}$	ANPP of the actual vegetation
$ANPP_h$	aboveground biomass harvested by humans; includes residues and burned biomass
$ANPP_t$	ANPP remaining in the system after harvest
$\Delta ANPP_{LC}$	change in ANPP through human induced land cover change
DM	dry matter
FAO	Food and Agriculture Organization of the United Nations
FMB	Forest Management Bureau (Philippines)
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
HANPP	Human Appropriation of NPP
IRRI	International Rice Research Institute
NAMRIA	National Mapping and Resource Information Authority (Philippines)
NPP	Net Primary Production
NSO	National Statistics Office (Philippines)
PhilRice	Philippine Rice Research Institute
UPLB	University of the Philippines, Los Baños
WTO	World Trade Organization

Introduction

Net primary production (NPP) is the amount of biomass fixed by autotrophs (i.e. mostly green plants) in a given period and thus, the amount of energy available for all heterotrophic life-forms in ecosystems. Human land use alters these energy flows to a significant degree, influencing a broad variety of ecosystem properties. The “human appropriation of net primary production” (HANPP) has been proposed as a measure of this human dominance, which it considers two-fold: i) through the effects of human-induced land cover/land use changes and ii) through biomass harvested through human activities.

With this study, I provide an assessment of HANPP in the Philippines from 1910 to 2003 on national level. To do so, I basically rely on statistical data available and model estimates were necessary. My study presents the first investigation of long term development of HANPP for a tropical developing country, with a colonial history.

The Philippines are a volcanic archipelago, consisting of over 7100 islands and belong to insular Southeast Asia (see Figure 1). Most of these islands are, however, uninhabited and the eleven largest islands constitute about 94% of the total land area, which is 29.8 Mha, excluding inland waters (FAO 2004). This total territory remained constant over the period observed. The three major groups of islands of the Philippines are (compare Figure 1):

- Luzon in the north, mainly composed by the island of the same name. It is the nation’s largest island (about 10.5 Mha); Manila, the capital of the Philippines is located there;
- Mindanao in the south, containing the second largest island of the archipelago (about 9.5 Mha); and
- Visayas between the two main islands, consisting of a group of medium sized islands.

Administratively, the Philippines are divided into 17 Regions and 81 Provinces (as of December 2006)[1]. The total population was estimated at 82 million capita in 2003. The climate of the islands is tropical and humid, with abundant rainfalls: 90 percent of the area receives over 1780 mm a year (Wernstedt and Spencer 1967). However, especially on the monsoon influenced western side of the archipelago, a distinct seasonality of dry and wet season exists.

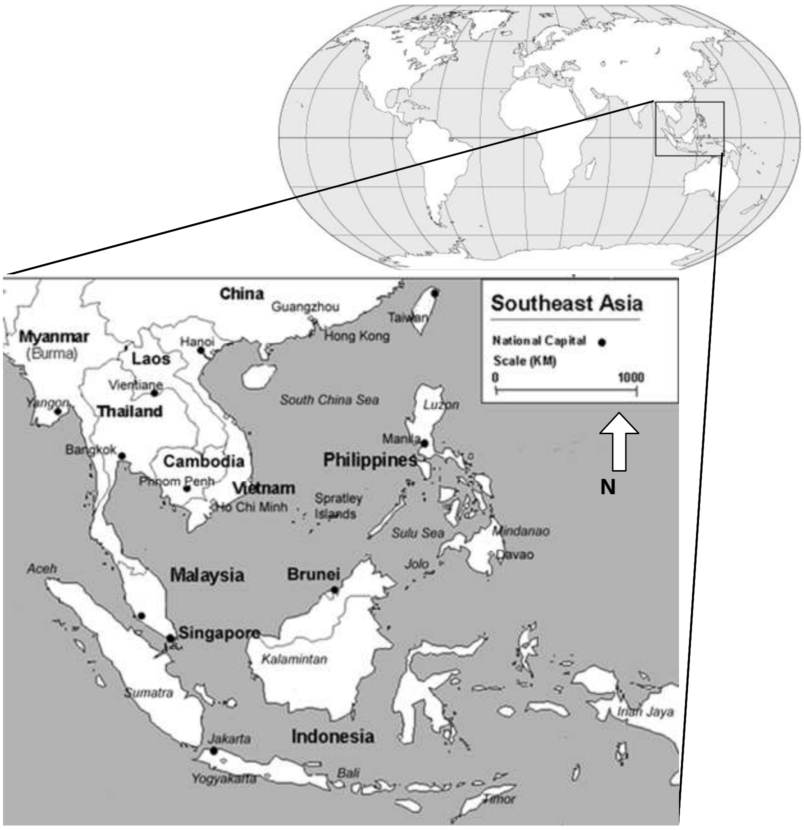

Figure 1 Location map of the Philippines

While the main islands, Luzon and Mindanao, contain major lowland areas, the Philippines are, in general, characterized by relatively narrow coastal plains and sloped inlands. About 55% of the total land area have a slope of 18% and higher and are considered uplands by Philippine legislation (Garrity et al. 1993). Soil types are varied, but in general, favorable and not greatly weathered compared to other humid tropical soils. However, also owing to the sloped

[1] Shariff Kabunsuan and Dinagat Islands were created as 80th and 81st Province in late 2006, respectively; http://www.statoids.com/uph.html, accessed January 15 2007

terrain and occurring heavy rainfall, serious soil erosion problems exist[2] (Wernstedt and Spencer 1967).

Only a very basic overview of Philippine history can be provided in the context of this study. The nation was a Spanish colony for over 333 years from 1565 to 1898. Through a period of war and turmoil at the turn of the 19th century, the Philippines became a colony of the United States of America. In World War II, the islands were occupied by the Japanese from 1941 to 1945. In 1946, they were granted independence from the US. They have been a republic since then, with the exception of the years 1972 to 1986. Over the mentioned period, they were under the reign of Ferdinand Marcos, who was elected president in 1965 and stayed in power by proclaiming martial law in 1972, thus establishing a dictatorship.

During the 94 years covered by this study, the Philippines have experienced rapid population growth and an overall ten-fold increase in capita, from 8.2 million in 1910 to 82 million in 2003. A number of migration movements were linked to this development. The most prominent of these being:

- migration towards the island of Mindanao which was virtually unsettled in Spanish times, as the Spaniards could never claim control over the major part of the island;
- later, this movement was accomplished by strong migration towards urban centers, above all, towards Manila;
- with the lowlands facing high population density and not enough land and labor for the growing population, the landless "poorest of the poor" often migrated into the uplands of the nation from the 1960s onwards, following commercial logging operations that had opened upland forests;
- recently, a strong emigration to other countries can be observed.

Economic performance has been erratic throughout the observed period, and while absolute gross domestic product (GDP) grew considerably, sustained per capita growth proved to be more difficult to establish; from 1925 to 2000 per capita GDP, in 1990 USD, rose only from

[2] Wernstedt and Spencer (1967), citing a study from Mamisao of as early as 1949, claim that as much as 76% of farmland and 30% of the total land area are subject to slight to severe erosion.

523 to 967 USD. During the 1980s, a decade of political and economical crises, it even declined significantly. GDP per capita, generated by the primary sector agriculture, stayed more or less constant over the period observed at about 200 1990 USD. The share of agriculture in total GDP gradually declined from 40% to 20%, while total agricultural population still remained as high as 39% in 2000.

The agricultural history of the islands can only be outlined here in a very crude manner. More detailed descriptions of at least parts of the developments can be found, for example, in Kolb (1941), Wernsted and Spencer (1967), Larkin (1982), Corpuz (1997), Reiterer (1997) and Hayami (2000). It is commonly believed that before the arrival of the Spanish, the majority of the population practiced various kinds of shifting cultivation, which was usually supplemented by fishing, hunting and gathering. Littoral dwellers were engaged in barter trade with passing vessels, mainly Chinese and Indian. While some kind of sedentary forms of subsistence existed[3], mobility was a key feature of most societies and population density was relatively low[4]. The Spanish forced the people into permanent settlements to be able to control the population, often through the church and its friars. In pre-colonial times, usufruct land use rights were common. The Spanish introduced European concepts of land ownership, thus facilitating the creation of a local elite, the establishment of plantations and the increase in tenant farmers. Permanent agriculture became a common feature under the Spanish reign and traditional forms only survived in the regions, they could not extent their control upon; prominently most of the island of Mindanao and the mountainous uplands of the archipelago. Over the course of the 19th century, growing demand for tropical products on the world market led to an orientation towards exports of agricultural products, with sugar, coconut, abaca[5] and tobacco as the leading cash crops. This development, along with a growing population, led to an imbalance in the domestic staple crop production and the Philippines became a net importer of rice in the late 19th century. During the US rule, the situation in the agricultural

[3] The most prominent example for this is the mountain people of Northern Luzon who are known for their magnificent rice terraces. However, they traditionally also practiced slash and burn agriculture on the nearby slopes as a supplement to the rice from the terraces (Kolb 1942).

[4] Corpuz' (1997) estimate of 1 to 1.25 million people at the arrival of the Spanish, which is somewhat higher than common estimates, would place population density at about 4 capita per km².

[5] Abaca, also called Manila hemp, of the banana genus (*Musa textilis*) is a fibre plant. It was mainly used to produce strong ropes but also a variety of other products.

sector remained more or less the same, but the export market became very closely linked to the US market, with some tariff free trade, between the colony and the US market. The Americans initiated large scale forestry operations, aiming at both the domestic and the export market (Bankoff 2006). With the exception of the sugar industry, Philippine agriculture stayed low in yields and without large scale external inputs, such as fertilizers and pesticides, until well after World War II and accomplished its growth in output, mainly through expansion of permanently farmed land. Growing population[6] led to again increased imports of rice and wheat. The founding of the International Rice Research Institute (IRRI) in 1960 can be seen as the starting point of agricultural intensification in the islands; focused mainly on the lowland, irrigated rice growing areas. In the so called developing nations, this process of intensification has been termed Green Revolution (Khush 2001). The second half of the 20th century was also characterized by the overuse, exploitation and decline of the countries natural forest resources, mainly in the uplands, which is well documented by Kummer (1991).

Table 1 Seleced socio-economic characteristics of the Philippines for the years 1925, 1960 and 2000

	1925	**1960**	**2000**
Area [Mha]	29.8	29.8	29.8
Population [millions]	11.7	27.4	76.5
Population density [capita per km²]	39.1	91.8	256.6
Agricultural [millions]		17.2	29.8
as percent of total population [%]		63%	39%
Total economically active population in Agriculture [millions]		6.4	12.4
GDP per capita [1990 USD/cap]	523	600	967
In agriculutre [1990 USD/cap]	205	180	191
share of agriculture in GDP [%]	39%	30%	20%

Table 1 presents some major socio-economic indicators for three selected years within the timeframe of my study. These figures underline some of the developments just described. With these general characteristics and historical developments in mind, this study aims to give a picture how society-nature relations in general and human influence on ecosystem flows in particular changed over the period observed. This is established by using the mentioned

[6] A population density of over 90 capita per km² in 1960 can be considered rather high for a society based mainly on agricultural forms of subsistence. Wernstedt and Spencer (1967) claim several times in their work that the country is in urgent need of an “agricultural revolution” to meet domestic demand.

HANPP framework. The following section tries to give a clear picture of the aims and scope of my research.

Aims and scope of this research

The primary goal of this study is to assess the historical development of HANPP in the Philippines on a national level and by doing so, to give a picture of occurring trajectories in society-nature relations. The timeframe was set from 1910 to 2003, with the exclusion of the World War II years 1941 to 1945. I have chosen 1910 as the starting point due to very limited availability of input data before that point in time. The values of HANPP and its components are calculated in a continuous time series. Where input data were not available on a yearly basis, I generally used linear interpolation between existing data points. Due to lack and inconsistency of much of the data on a provincial and regional level, spatial disaggregation proved to be impossible within the scope of this study. Following the latest definition of HANPP, I assess NPP forgone through human-induced land use/land cover changes, NPP harvested and NPP burned through human induced fires (the latter is included in biomass harvest). While recognizing the importance of marine ecosystems in a nation compromised of numerous islands and hardly any inland point farther than 50 km from the coast, the research is limited to the terrestrial component of NPP. This is due to lack of necessary input data and for methodological reasons. Further, owing to limited availability and quality of data on belowground productivity, this study calculates NPP flows for the aboveground component only, which is abbreviated ANPP. Biomass flows are expressed in tons dry matter per year (t DM/a) or in tons dry matter per hectare and year (t DM/ha/a) for per unit area values.

Research questions addressed in this study include:

- How did the development of HANPP in the Philippines change over the period of 1910 to 2003, and how can the observed development be placed in the specific national context?
- How has land use evolved, and how much did land use changes contribute to the observed development of HANPP?
- How did foregone and harvested ANPP change over time, and how did their ratio evolve?

- What is the relation between the "population explosion" and HANPP? Were increases in efficiency of NPP appropriation necessary, and if so, how were they achieved?
- Is it possible to satisfactorily incorporate phenomena such as rapid deforestation and "slash and burn" into HANPP calculations, with the data available?
- Can the assessed HANPP developments be linked to in socio-economic trends such as energy consumption, GDP development and biomass trade?

Tackling these questions will hopefully help to deepen the understanding of changes in society-nature relations and provide valuable insights in occurring trajectories of a tropical developing nation.

Methods, Materials and Data Sources

This section presents a basic overview of the concept of HANPP. Thereafter, I present, in detail, the methodology and data sources I used to calculate, and assess the components necessary for the final calculation of HANPP over the time series. I try to give clear and detailed definitions of HANPP and methodological descriptions to render my work comparable to existing and forthcoming studies.

The concept of HANPP

A detailed definition of HANPP as used in this study can be found in a number of sources (e.g. Schandl et al. 2002, Haberl et al. 2004 and Haberl 2006). Here, only a general overview of the HANPP concept is given. Methodological adoptions that were necessary to fit it into the context of this study will be discussed. HANPP as an environmental indicator was first proposed by Vitousek et al. (1986) and later on defined as the difference between the NPP of the potential vegetation and the NPP remaining in the system after harvest (Haberl 1997, Haberl et al. 2004). The human influence on ecosystem flows is considered through two activities: i) the alteration of NPP through human-induced land cover change (ΔNPP_{LC}) and ii) biomass harvest (NPP_h). The formula used to calculate HANPP is:

$$HANPP = NPP_0 - NPP_t$$
with $NPP_t = NPP_{act} - NPP_h$

or

$$HANPP = \Delta NPP_{LC} + NPP_h$$
with $\Delta NPP_{LC} = NPP_0 - NPP_{act}$

where

HANPP	NPP appropriated by humans
NPP_0	NPP of the potential vegetation
NPP_t	NPP remaining in the system after harvest
NPP_{act}	NPP of the actual prevailing vegetation
NPP_h	NPP harvested by humans
ΔNPP_{LC}	NPP change by human-induced land cover change

As mentioned before, this study calculates aboveground NPP flows only (ANPP). The unit used is tons dry matter per year (t DM/a).

Data availability and quality

Before I give a detailed description of the data used, I want to shortly remark on the data situation in the Philippines has to be made. In general, data availability and quality leave a lot to be desired. Data sets are often incomplete, inconsistent or lacking clear definitions. However, using primary and secondary data sources, I tried to establish data sets that were as consistent as possible, and while single data points might be questionable in detail and data quality might not be comparable to that in so-called developed nations, the general picture of many aspects and trends of the biophysical development of the Philippines over the last century is well-founded.

Land use data set

A land use data set is crucial for calculating HANPP. Establishing a consistent time series of land use for the Philippines proved to be a challenging task. Land-use data for the whole nation is not readily available, due to inconsistencies in much of the official data (Kummer 1991, Bankoff 2006 and Stenberg and Siriwardana 2007). My approach was to establish a "best guess" for a continuous land use data set, using the data at hand. Since the main interest for this study is to differentiate land uses with regard to their productivity, I made the distinction between different categories with expected ANPP differences in mind. Basically, I distinguish four main categories:

- forest land
- farmland

- grass- and brushland[7]
- minor other land uses (including built-up land)

Data availability concerning these categories varies very much. They were at first established independently and were summed up to give the total country area. Linear interpolation was used to obtain values for years missing between two existing data points. The following section gives a detailed overview on data sources and assumptions used for the four main land use categories.

Forest land

The forest land category consists of three subcategories:

- closed forests
- open forests
- mangrove forests

The official definition of forest land in the Philippines is of little use in the context of this study, because it is a legal definition and is not related to the actual prevailing land cover/land use (Kummer 1991, Pulhin et al. 2006 and Sheeran 2006; simplified all land with a slope over 18% are defined as uplands and as forest land and considered state property). In this study, forest land is defined as land with a certain minimum percentage of tree cover. While earlier estimates on extent of forest cover lack a clear definition of a threshold, recently it has become common to use a value of 10% tree cover and above to classify land as (open) forest (World Bank 1989, National Mapping and Resource Information Authority (NAMRIA 2004 and FAO 2006). There are a number of publications dealing with the history of Philippine forests over the last century (e.g. Kummer 1991, Pulhin 1996, Lasco and Pulhin 2000a, Lasco et al. 2001 and Bankoff 2006). On the one hand they all agree that data availability, quality

[7] I use the term brushland for land covered by woody elements such as shrubs, bushes and young trees; this is common in literature on the Philippines and in Philippine land use classification (e.g. Garrity and Agustin 1995, Magcale-Macandog and Nishioka 2000, Lasco et al. 2002 and Sheeran 2006).

and consistency pose large problems concerning a profound discussion of development of extent and composition of Philippine forest land[8]. On the other hand, available publications commonly agree that within the time span considered in this study, the following trends regarding forest land occurred:

- Dramatic loss of forest cover (Kummer 1991, Lasco and Pulhin 2000b and Bautista 1990): a decline from about 70 percent land area covered by forests at the turn of the last century to about 20 percent of total land area is now commonly mentioned and accepted[9].
- Fragmentation of the remaining forest land, extension of forest fringes (Liu et al. 1993 and Verburg and Veldkamp 2004).
- Relative increase of open forests as compared to closed forests (Kummer 1991 and Richards and Flint 1994).
- Sharp decline of primary forests, relative increase of secondary forests (Kolb 1942 and Lasco et al. 2001).

Early records of Philippine forest cover are mostly nationwide estimates by colonial authorities, distinguishing between so-called commercial and non-commercial forests. Such historical estimates (e.g. Division of insular affairs 1901, Census Office of the Philippine Islands 1920 and Kolb 1942) are compiled in Kummer (1991), Richards and Flint (1994) and Bankoff (2006). More recent inventories and satellite data differentiate between a wider range of forest types. However, these studies' categories are not consistent among each other. To this day, there is a lack of forest inventories for the Philippines with completely published results. Two inventories were conducted, one in the second half of the 1960s and the other from 1983 to 1988, but publications of results are incomplete on disaggregated levels (Kummer 1991)[10].

[8] Numbers on total forest cover from the FAOs latest Global Forest Resource Assessments (FRA) in 2000 and 2005 serve well to exemplify the often contradictory data on forest cover (FAO 2001 and FAO 2006). The FRA 2000 gives a total of 6.7 Mha forested in 1990, the FRA 2005 has 10.6 Mha for the same year. For the year 2000, the numbers are 5.8 Mha and 7.9 Mha respectively.

[9] During my research in the Philippines, a dramatic mudslide occurred in a village in the province of Southern Leyte, with a death toll over 1 000 people. In the public media coverage, the mentioned forest decline from 70% to 20% was frequently presented and deforestation commonly blamed for the disaster.

[10] For this study, however, I decided not to use the available aggregates of these inventories but data based on aerial photography/satellite imagery from the years 1969 and 1987 since the latest data point of 2003 is based on

Two land cover data sets derived from satellite imagery are available at a national level for the years 1988 and 2003 (World Bank 1989 and NAMRIA 2004).

To be able to maintain a certain level of consistency over time, I only distinguished between open and closed forests as given in studies using aerial photographs and satellite imagery (Bonita and Revilla 1969 cited from Bautista 1990, World Bank 1989 and NAMRIA 2004). This very broad distinction makes sense with respect to the focus of this study, i.e. productivity of the respective areas. Closed forests are often defined as forests with a crown cover over 50 percent (World Bank 1989). However, in the most recent definition of NAMRIA (2004), the threshold value is lowered to 40 percent. This corresponds with the definition given by the FAO in its latest Global Forest Resource Assessment (FAO 2006). Secondary literature (Division of insular affairs 1901, US Bureau of Census 1905 and Kolb 1942) revealed that the categories “commercial” and “non-commercial forests” were defined on the basis of the volume of marketable wood left in the forest. Non-commercial forests were usually logged over forests with little commercial wood left in them. I therefore used this category synonymously with open forests from more recent data sets, while commercial forests were put into the closed forest category. The data points for total forest cover before 1969 originated from a recent reappraisal of deforestation rates prior to World War II (Bankoff 2006). To estimate the respective share of “commercial” and “non-commercial” forest additional sources were used (details see Table 2).

Primavera (2000) compiled data for the development of mangrove area in the Philippines. These data were used for the corresponding category. Since it is assumed that mangroves are included in the total forest area estimates of Bankoff (2006), I subtracted mangrove area from his totals. The extent of established forest plantations in the Philippines is relatively low. Only the latest satellite study by NAMRIA (2004) includes forest plantations as a separate category and places them at about 300 kha. While promotion of economically and environmentally sound plantations is common, their establishment is hindered by a number of reasons: e.g. policy and enforcement issues, tenure issues (Pulhin 1996). Because of the lack of a distinct

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satellite data. Also, data before 1969 does not allow for the distinction of the various categories of the inventories.

category for plantation before 2003, I decided to include the extent of plantations as reported by NAMRIA (2004) in my category of open forests.

Table 2 shows the area values used for the closed and open forest and names the data sources. Table 3 presents the development of mangrove and fishpond area mainly after Primavera (2000).

Table 2 Data on forest cover in Mha used for my land use data set and sources

Year	Closed forests	Open forests	Source
1875	17.02[1]	1.89[2]	Bankoff 2006 and Division of insular affairs 1901
1918	15.73[1]	2.64[2]	Bankoff 2006 and Census Office of the Philippines cited from Bureau of Commerce and Industry 1923
1932	13.46[1]	3.06[2]	Bankoff 2006 and Kolb 1942
1950	10.58[1]	3.82[2]	Bankoff 2006 and Richards and Flint 1994
1969	5.94	3.86	Bonita & Revilla based on a large scale photograph interpretation cited from Bautista 1990
1987	3.13	3.83	World Bank 1989
2003	2.66	4.37	NAMRIA 2004; note that the category open forests contains the NAMRIA category "forest plantations"

[1] refers to "commercial forests", [2] to "non-commercial forests"; details see text

Table 3 Development of area of mangroves and fishponds in kha

Year	Mangroves	Fishponds
1860		[1]
1920	450	no data
1940		61
1950	418[2]	73
1960	365[3]	123
1970	288	168
1980	242	176
1990	133	223
1994	120	232
1997	112	
2003		244

Sources: 1860 - 1994: various sources from Primavera 2000, 1997: FMB data in NSO 2005b; 2003: NAMRIA 2004, 2003 fishpond value probably underestimation due to satellite data;
[1] first fishpond recorded in 1863; [2] value for 1951; [3] value for 1965

Farmland

Farmland is defined here as land under permanent cultivation and land held by farmers with legal titles with exception of settlement areas and homesteads (which I include in the category settlement and infrastructure). Farmland is divided into three subcategories: land devoted to annual crops, land devoted to permanent crops, and other farmland (containing fallowed farmland, farmland used as pasture, farmland with forest growth).

Data on area planted to annual and permanent crops is available for crops of major importance throughout the studied period (Bureau of Commerce and Industry 1918, 1923, 1928, Division of Agricultural Economics 1954, Dy 1998, NSO 2005b and Bureau of Agricultural Statistics, 2006, personal communication). The number of reported crops increases over time, which might reflect a development of diversification, but might also have its origin in underreporting in earlier years and therefore could lead to an underestimation in these periods (see Table 12 below). In general it can be assumed that at all time minor subsistence crops are grown to some extent on the category other farmland and that areas of shifting cultivation are in general underrepresented within the data. The whole area of farmland is surveyed in the Philippines through the Censuses of Agriculture which were conducted at several points in time over the period observed (1903, 1918, 1939, 1948, 1960, 1971, 1980, 1991, 2002, cited from Bureau of Commerce and Industry 1923, Bureau of the Census and Statistics 1971 and NSO 2005a). Table 4 shows compiled aggregate data of census data. Note that the methodologies and definitions are not consistent throughout the different censuses. Therefore, full comparability is not given (NSO 2005a) and the numbers just give a picture of general trends in land use development.

Table 4 Area data on farmland categories in Mha

	1903	1918	1939	1948	1960	1971	1980	1991	2002
Annual cropland	n.d.	n.d.	n.d.	n.d.	3.78	3.89	4.37	5.33	4.82
Lands lying idle	n.d.	n.d.	1.11	0.84	1.12	0.75	0.84	0.15	0.12
Permanent cropland	n.d.	n.d.	n.d.	n.d.	1.80	2.53	3.49	4.17	4.23
Permanent meadows	n.d.	n.d.	0.73	0.47	0.38	0.69	0.53	0.13	0.13
Forest growth	n.d.	n.d.	0.65	0.51	0.58	0.43	0.34	0.07	0.07
All other lands	n.d.	n.d.	0.25	0.20	0.11	0.19	0.17	0.11	0.27
Total cultivated	1.30	2.42	3.95	3.71	5.58[1]	6.42[1]	7.85[1]	9.51[1]	9.04[1]
Total uncultivated	1.53	2.15	2.00[2]	1.55[2]	1.81[2]	1.38[2]	1.34[2]	0.34[2]	0.46[2]
Total farmland	2.83	4.56	5.96	5.26	7.40	7.80	9.20	9.84	9.50

Source: Different censuses of agriculture cited from Bureau of Commerce and Industry 1923, Bureau of the Census and Statistics 1971 and NSO 2005a; [1] sum of annual and permanent cropland; [2] sum of lands lying idle, permanent meadows, forest growth and all other lands

When using yearly data on the area devoted to annual crops agricultural statistics an important fact has to be considered: this area data refers to area planted (or harvested). In the tropics, it is a common practice to plant more than one crop per year, a practice often called multi-cropping. Therefore, to arrive at an estimate of the physical area assumptions had to be made for multi-cropping intensity. These intensities vary over time. Besides the choice of crops, they depend on climatic and soil conditions and on the level of industrialization of agriculture (e.g. Shriar 2000). In this study I define cropping intensity as the number of crops that are planted in one spot of land over the time span of 1 year. Areas fallowed or taken out of cultivation are not considered to be included in the original area data in the agricultural statistics and therefore are not part of my assumptions here. E.g. a cropping intensity of 150% means that on average 1.5 crops are planted per year on a given area. My assumptions were made separately for the major crops and are mainly based on PCARRD (1978, 1981, 1983), Phil-Rice (1997), Hillocks et al. (2002) and IRRI 2006). In general, I assume that cropping intensities remain more or less constant before the agricultural modernization in the 1960s. Table 5 shows the used cropping intensities for major annual crops and selected years. The area values obtained with these assumptions fit well with the values for physical annual and permanent crop areas given in the Censuses of Agriculture. Data on total farmland area is taken from these censuses and interpolated for the years between two censuses. The category "other farmland" is assumed to be the difference of total farmland and annual and permanent cropland. Further, a certain share of land devoted to settlements and infrastructure is subtracted and assigned the respective category (details see below).

Table 5 Cropping intensities for selected years and main sources

Crop	1910	1939	1970	2000	Sources
Rice	118%	119%	128%	167%	PCARRD 1981, Philippine Rice Research Institute 1997, IRRI 2006
Corn	143%	143%	147%	165%	PCARRD 1978
Cassava	167%	175%	191%	229%	PCARRD 1983, Hillocks et al. 2002

Grass- and brushland

In general this category contains manmade, secondary vegetation forms, since the Philippines' natural vegetation is considered almost exclusively forest cover (Kolb 1942 and Bankoff 2006). Regarding their extent, grass- and brushland are important categories but data availability is very limited. Another problem is the lack of clear definitions. To a very large share grasslands in the Philippines are dominated by *Imperata cylindrica* and are often found on degraded sloped land (Garrity et al. 1996 and Snelder 2001). They are usually grazed by livestock like cattle, goats and carabao (local name for the Asian water buffalo *Bubalus bubalis*), but at a very low stocking level (0.25 to 0.5 animal units per hectare are common; Batcagan 2000). The distinction between grassland, brushland and forest land is a question of thresholds. Brushlands in the Philippines can be seen as an intermediate between forests and grasslands. They are usually found on previously cleared land and they could return to forest land if pressure on them was low. Often they are grazed and used for fuel wood extraction if they are close to settlement areas (Lasco in Canadell 2001). Fallowed land that has been under agricultural use for some years can also fall into this category if it has not yet had the possibility to re-grow into a proper forest (Lasco et al. 2001). During the studied period studied, an increasing pressure on the land and shortened fallow periods in shifting cultivation occurred (Olofson 1981, Collins et al. 1991 and Lawrence 1997). Under such conditions a full re-growth into forest is often no longer taking place and a spatial mosaic of grassland, brushland and land under agricultural cultivation is formed in which land use frequently changes between these different uses (World Bank 1989 and Lasco in Canadell 2001).

Historical sources usually do not give clear definitions of grassland, while brushland is often referred to as "submarginal land" or "reproductive brush" (Kummer 1991 and Richards and Flint 1994). Kolb (1942) and Wernstedt and Spencer (1967) give qualitative descriptions of large man-made grassland areas that already existed in the first half of the last century also stating the importance of *Imperata* lands (the grass is locally know as cogon). Data sources for the grassland category over time were: The Censuses of 1919 and 1932, Serevo (1959) as cited in Richards and Flint (1994). Serevo's values for grassland and brushland can be considered underestimates. His value for cultivated land is much higher than the reported Census of Agriculture data; most likely because he included land that had been taken out of use in this category. Therefore, 50 percent of the difference between his value for cultivated land and the value for farmland used in this study are included in the category of grassland. The other 50 percent are considered to be brushland. The next point in time for which data on the extent of grassland was used is 1991 from a land use data set of the Bureau of Soils and Water Management as cited in Philippine Economic-Environmental and Natural Resources Accounting (2004). The final data point was taken from NAMRIA (2004) and contains its categories of grassland and wooded grassland (*"Land where the trees cover between 5 to 10% of the area and their height may reach 5 m at maturity"*). It further includes 50% of the difference between the cropland NAMRIA reports and farmland corresponding to the 2002 Census of Agriculture. This is due to the fact that the satellite imagery is not able to detect small patches of grassland and brushland between cropland and therefore, gives an overestimation of crop area. The other 50% are considered in the brushland category.

Facing data limitation and having obtained qualitative information from literature, I assume the area for brushland to be the difference between total land area and the sum of all other land use categories. I decided to use this pragmatic approach for a number of reasons: In existing data, the area of brushland increases over the observed period and in early statistics this category is not accounted for at all. It is a very heterogeneous category with varying definitions (see above). Available data (e.g. as compiled by Richards and Flint 1994) fitted well with my assumption. It is assumed that this category contains (compare Lasco et al. 2001):

- land taken out of agricultural use and now in a regenerating state (see above)
- logged over land with strong pressure (e.g. wood fuel collecting, but also grazing) on it and therefore not given the chance to regenerate into a proper forest again
- in the uplands it probably contains land under actual cultivation for a few years (mostly by swidden agriculturists; more recently probably also areas under agroforestry development). Such land might be underestimated in the official Census

of Agriculture data, since swidden farming is often practiced without legal land titles (Rice 1981 and Pulhin 1996)

Minor other land uses

The category minor other land uses consists of three subcategories: infrastructure and settlement area, fishpond areas, and barren land. There are no historical data available on infrastructure and settlement areas and recent satellite data tend to underestimate them. Due to this limitation, a model developed at the Institute of Social Ecology was used (Haberl et al. 2007a) to calculate these areas. This model incorporates population density and development level to derive an estimate for settlement area. Using the model's standard values and due to the rapid increase in population density, it was estimated that average per capita area demand in this category declined from 150 m² in 1910 to 75 m² in 2003. The value of 539 kha obtained by the means of this model assumption for 1991 is very close to the value reported by the Bureau of Soils and Water Management (in Philippine Economic-Environmental and Natural Resources Accounting 2004) for the same year (526 kha). This can be seen as a validation of the used model data. I assumed a share of the category "other farmland" to be actually used as settlement and infrastructure area, since settlements and infrastructure are usually close to farmland. This is also in accordance with the definition of other farmland in NSO (2005a). Therefore the respective numbers were substracted from the farmland category for each year. For the development of fishpond area, data were taken from Primavera (2000; see Table 3 above). Data for barren land were taken from NAMRIA (2004) and cross checked with the Bureau of Soils and Water Management data for 1991 (Philippine Economic-Environmental and Natural Resources Accounting 2004). This category includes rock land, beaches, etc. and is considered constant over time.

Synthesis of the data sources for my land use data

Table 6 gives an overview of the categories used and the main data sources. As a caveat, I note that this data set was prepared with the above-discussed sources and assumptions, reflecting on the aim of this study, i.e. assigning ANPP values to the different land-use categories. Data presented here should be considered as best guess of a consistent historical land use data set on national level useful primarily for this purpose. This approach also made it impossible to use more detailed data sets, available for recent points in time because historical records do not allow for a more detailed land use classification.

Table 6 Data sources of the presented land use data set

Category	Subcategory	Sources
Forest land	Closed Forests	Various sources as complied in Kummer 1991 and Richards and Flint 1994, NAMRIA 2004, Bankoff 2006
	Open Forests	Various sources as complied in Kummer 1991 and Richards and Flint 1994; NAMRIA 2004, Bankoff 2006; for the year 2003 the NAMRIA category "forest plantations" is included
	Mangrove Forests	Primavera 2000 and NSO 2005b
Farmland	Annual Crops	Bureau of Commerce and Industry 1918, 1923, 1928, Division of Agricultural Economics 1954, Dy 1998, NSO 2005b, BAS, 2006, personal communication; own calculations, see text
	Permanent Crops	Bureau of Commerce and Industry 1918, 1923, 1928, Division of Agricultural Economics 1954, Dy 1998, NSO 2005b
	Other farmland	Censuses of Agriculture data as compiled in Bureau of Commerce and Industry 1923, Bureau of the Census and Statistics 1971 and NSO 2005a; details see text
Grass- & brushland	Grassland Area	estimated development from various sources and estimates as compiled in Richards and Flint 1994, Philippine Economic-Environmental and Natural Resources Accounting 2004, details see text
	Brushland	Remainder category, assumptions based on literature (e.g. Lasco et al. 2001) and data (Richards and Flint 1994, NAMRIA 2004), details see text
Minor other land uses	Settlement and Infrastructure Area	model assumption taken from Haberl et al. (2007a)
	Fishpond Area	Primavera 2000 and NSO 2005b
	Barren Land	NAMRIA 2004 checked with Philippine Economic-Environmental and Natural Resources Accounting 2004

Aboveground productivity of potential vegetation ($ANPP_0$)

Within the HANPP concept, the NPP of the vegetation that would prevail without human influence (Tüxen 1956) is termed NPP_0. This productivity is used as a reference to compare human influences to the assumed original state of the studied system. It is widely believed that without human influence, forests would cover almost the entire area of the Philippines (e.g. Bautista 1990) and for 1565 – the year of the arrival of the Spanish, forest cover has been estimated at about 93 percent (Bankoff 2006). Using the climate classification after

Köppen (1936), the FAO proposes the following distribution of ecological zones (compare Figure 2; for details on the FAO's classification methodology see Davis and Holmgren 1999):

- tropical rainforest as the main ecological zone on the archipelago (about 75%)
- tropical moist deciduous forest covering relevant parts on the monsoon influenced west coast of the islands (about 20%)
- tropical mountain forests on and around the nation's highest summits (about 5%)

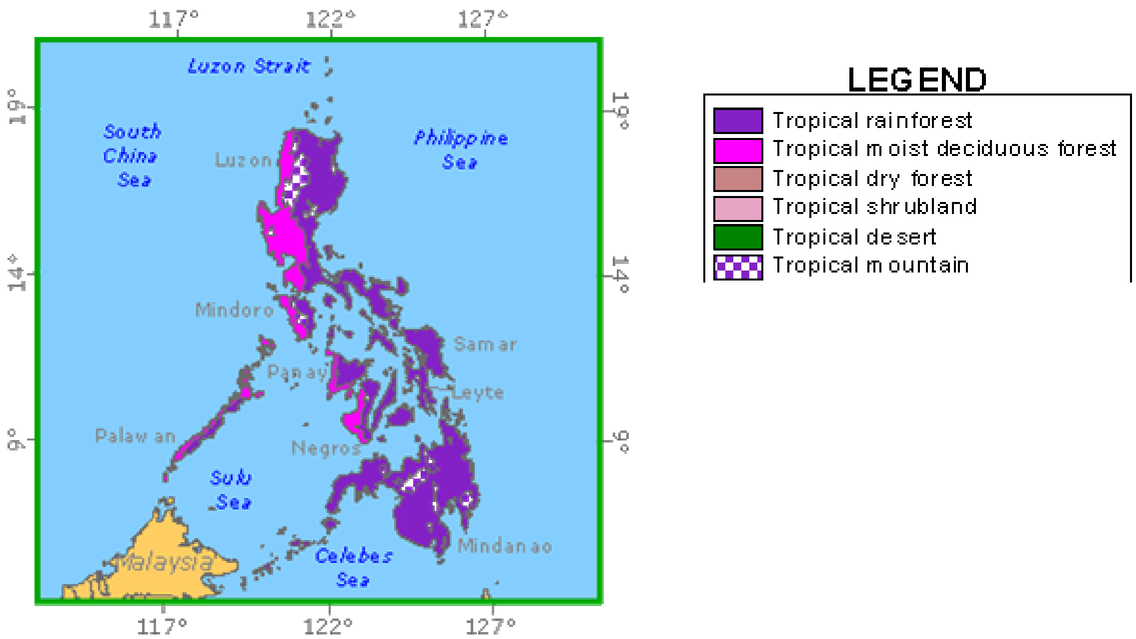

Figure 2 Ecological zones of the Philippines according to FAO (http://www.fao.org/forestry/en/, accessed January 12, 2006)

In this study, $ANPP_0$ data from a model run of the Lund-Potsdam-Jena Dynamic Global Vegetation Model (LPJ-DGVM) are used (Sitch et al. 2003 and Müller et al. 2006). For details on this model and its use in HANPP calculations see Haberl et al. (2007a). To validate the use of these values, I compared the results of the model with literature data on ANPP of Philippine forests and tropical forests in general (Rodin et al. 1975, Kawahara et al. 1981 and Lasco et al. 2004a). The value for $ANPP_0$ of the LPJ model run is an average value for the years 1998 to 2002. Due to the absence of reliable data or assumptions, $ANPP_0$ was assumed to have been constant at this value. However, in reality, NPP shows a strong yearly variability, and part of this variability is due to climate changes resulting from anthropogenic emissions of greenhouse gases (Ichii et al. 2005). Table 7 shows $ANPP_0$ values on different land uses in Haberl et al.'s study (2007a), Erb, 2006, personal communication). Since these values show a very low standard deviation, $ANPP_0$ is assumed to be constant at 11.65 for all land uses, with the exception of barren land for which an $ANPP_0$ of zero is assumed.

Table 7 $ANPP_0$ values from Haberl et al.'s (2007a) global mapping of HANPP.

Land Use for the year 2000 (according to Haberl et al. 2007a)	**Area in 2000** Mha	**$ANPP_0$ total** Mt DM/a	**$ANPP_0$ per ha** t DM/ha/a
Cropland	10.63	124.04	11.67
Grassland	11.33	130.73	11.53
Builtupland	0.56	6.34	11.33
Forest	6.13	72.86	11.89
Wild	1.08	12.34	11.46
Total	29.73	346.32	11.65
Standard Deviation			0.21

These values were derived using the LPJ-DGVM and assigning its results to different land uses in the year 2000 (Erb, 2006, personal communication)

Aboveground productivity of the actual vegetation ($ANPP_{act}$)

For the calculation of HANPP it is crucial to calculate the productivity of the actually prevailing vegetation. In studies dealing with recent years, NPP data from satellite imagery are often used. Since this is not possible in a historical study such as this one, I basically used a book-keeping approach to derive an estimate of aboveground NPP of the actual vegetation ($ANPP_{act}$). Different ANPP values per unif area were assigned to different land uses. Table 8 indicates the main data sources and estimates used.

For closed forests and mangroves, $ANPP_{act}$ was assumed to be $ANPP_0$, which was crossed checked with literature data (Kawahara et al. 1981 and Lasco et al. 2004a). Grasslands in the Philippines are mostly dominated by *Imperata cylindrica* locally known as cogon grass (Garrity et al. 1996 and Pasicolan et al. 1996). By far, most of them are man-made and they are usually found on degraded soils (see above). This general statement can be considered true for the whole period observed according to qualitative descriptions of grassland areas in historical sources (Division of insular affairs 1901, Kolb 1942 and Wernstedt and Spencer 1967). The $ANPP_{act}$ value used for grassland is the average of values given by Penafiel (1979), Falvey et al. (1981) and Batcagan (2000). I assumed that $ANPP_{act}$ on grasslands declined slightly from 6 t DM/ha/a to 5 t DM/ha/a in 2003, due to an increasing amount of degradation (e.g. Wernstedt and Spencer 1967, Batcagan 2000 and Department of Agriculture-Bureau of Soils and Water Management et al. 2004).

Table 8 Data sources of the used $ANPP_{act}$ values

Category	Subcategory	Sources
Forest land	Closed Forests	ANPP of the potential vegetation ($ANPP_0$) via LPJ-DGVM (Erb, 2006, personal communication); cross checked with Kawahara et al. 1981, Lasco et al. 2004a
	Open Forests	Own estimate: weighted average: 75% $ANPP_0$, 25% grassland value; details see text
	Mangrove Forests	ANPP of the potential vegetation via LPJ-DGVM (Erb, 2006, personal communication); cross checked with Lasco et al. 2004b
Farmland	Annual Crops	Own estimate via harvest indices and pre-harvest loss factor; details see text
	Permanent Crops	Own estimate: weighted average: 75% $ANPP_0$, 25% grassland value; cross checked with Banzon and Velasco 1982, Foale 2003, Mialet-Serra et al. 2005; details see text
	Other farmland	Average value of open forests, grassland and brushland
Grass- & brushland	Grassland Area	Penafiel 1979, Falvey et al. 1981, Batcagan 2000
	Brushland	Own estimate: weighted average 60% $ANPP_0$, 40% grassland value; details see textn
Minor other land uses	Settlement and Infrastructure Area	Estimated one third of $ANPP_0$ following the assumptions in Haberl et al. (2007a)
	Fishpond Area	Assumed zero; details see text
	Barren Land	Assumed zero; details see text

The values used for open forests and brushland are differently weighted values of forest and grassland values, since there is a lack of reliable ANP_{Pact} data for these types of land use (see Table 9). The rationale of using average values is that open forests/brushlands are a mix of grass covered vegetation with trees and woody elements[11]. For infrastructure and settlement areas, $ANPP_{act}$ was assumed to be a third of $ANPP_0$, according model assumptions used by Haberl et al. (2007a). Barren areas and fishponds were assigned an $ANPP_{act}$ of zero. In the

[11] A note has to be made concerning the 2003 value for open forests, since it also contains the area of the NAMRIA category "forest plantations". It is acknowledged that sound forest plantations can have a productivity similar to or higher than the potential one (Kawahara et al. 1981). In the context of the Philippine reality, however, plantations were and are often faced by a number of hindrances and therefore, not well established (e.g. insecure property rights, licenses issued for too short periods to encourage proper management, etc.; compare Pulhin et al. 2006). Therefore, it seemed justifiable to keep them in the open forest category and assign the same productivity; also, their extent is comparably low – in 2003, they composed less than 7% of the whole area considered open forest.

case of fishponds, this is so because this study considers terrestrial aboveground NPP only. Land covered with permanent crops was assigned the same value as open forests. This assumption was cross checked with literature on coconut plantations (Banzon and Velasco 1982, Foale 2003 and Mialet-Serra et al. 2005) which are by far the most important permanent cropin the Philippines making up about 90 percent of the total permanent crop area throughout time. For the category other farmland, $ANPP_{act}$ is considered the average of open forests, grassland and brushland values.

A different approach was used to estimate $ANPP_{act}$ for annual cropland. So-called harvest indices were used to calculate the actual crop biomass from the statistically available data on commercial harvest. The harvest index (HI) is the ratio of the commercial harvest of a crop to its total aboveground biomass (Evans 1993). For annual crops, the total biomass before harvest can be considered to equal the biomass increment for one growing season. To account for biomass of weeds and biomass consumed by herbivores a so-called pre-harvest loss factor was used. This factor was derived from Oerke et al. (1994) and is assumed to be 1.36 in the time period from 1910 to 1960; after that a gradual decline to 1.23 in 2000 was assumed, reflecting agricultural modernization; for details see Haberl et al. (2007a). The $ANPP_{act}$ of land planted with annual crops is: $NPP_{act} = \frac{H}{hi} * phl$

where
H…commercial harvest
hi…harvest index
phl…pre-harvest loss factor

Aboveground biomass harvested by humans ($ANPP_h$)

Societal biomass harvest was calculated using statistical sources wherever possible, with certain assumptions to fill data gaps where necessary. Four functional types of human harvest were distinguished:

- Agricultural crop harvest
- Biomass grazed by domesticated animals
- Wood harvest

- Human-induced fires

It is important to note that these harvest types generally contain by-products that have other uses than the main product (e.g. by-products of food crops can be used as fuel). Also, harvested by-product biomass can have no specific use and be burned or decay on site. In the latter case this harvest was included in ANPPh but separately reported as a backflow to nature (cf. Haberl et al. 2007a). Tables 9 and 10 show the different parts of $ANPP_h$ that were considered and how they were assigned to different land uses and societal uses.

Table 9 Assignment of the different $ANPP_h$ types to different land use categories

$ANPP_h$ type → Land use↓	Agricultural crop harvest	Grazing	Wood harvest	Human-induced fires
Closed Forests			■	■
Open Forests		■	■	■
Mangrove Forests			■	■
Annual Crops	■			■
Permanent Crops	■	■		■
Other farmland		■		■
Grassland Area		■		■
Brushland		■	■	■
Settlement and Infrastructure Area			■	■
Fishpond Area				
Barren Land				

■ combination considered; □ combination not considered

Table 10 Assignment of the different $ANPP_h$ types to different uses (commercial harvest and by-products considered)

Use→ $ANPP_h$ type↓	Agricultural crop harvest	Grazing	Wood harvest	Human-induced fires
food	■			
feed	■	■		
fuel	■		■	
building/other uses	■		■	
backflow burned	■		■	■
backflow decay	■	■	■	

■ combination considered; □ combination not considered

It has to be noted here for settlement and infrastructure areas due to the lack of harvest data, I used the following simple assumption: half of the actual ANPP was considered to be harvest and of this harvest two thirds were considered to have been used as fuel, and one third as other uses (e.g. ornamental).

Agricultural crop harvest

Cropland is cultivated by human societies to produce food and other resources needed. My HANPP calculation considers all aboveground biomass killed in the process of harvest on agricultural land as appropriated, regardless of its societal use. Statistical data however, are commonly only available for commercial crop harvest[12]. In the Philippines, such data along with data on the area planted exists from 1910 onward on a yearly basis for major crops. Values were compiled from various sources (Bureau of Commerce and Industry 1918, 1923, 1928, Division of Agricultural Economics 1954, Dy 1998, NSO 2005b and Bureau of Agricultural Statistics, 2006, personal communication). As mentioned earlier, recent statistics give a wider variety of crops. Table 12 shows the reported crops for four selected years. Over the course of the century, the crops reported in agricultural statistics increased from 6 to 25. Still, the share of the six crops reported initially (rice, corn, coconut, sugarcane, abaca and tobacco) – while somewhat declining – is predominant throughout the whole period.

All harvest data were converted to dry matter values using standard tables on food and feed composition (Watt and Merrill 1975, Löhr 1993 and Souci et al. 2000), and wherever possible from country specific sources (PCARRD 1983, 1988). The factors and sources used are compiled in Table 11.

Five crops were accounted for in the permanent crops category: coconut, coffee, mango, rubber and cacao. The other crops were considered annual crops.

[12] Agricultural crop harvest in total consists of commercial crop harvest plus harvested by products. The latter also includes biomass that decays or burns on site (backflow to nature; see above).

Table 11 Water contents of the crops reported in Philippine agricultural statistics

Crop	Water Content	Sources
Rice	14%	standard tables on food and feed composition[1]
Corn	14%	standard tables on food and feed composition
Coconut	40%	standard tables on food and feed composition; Banzon and Velasco 1982
Sugarcane (stalks)	73%	IRRI 1983
Banana	72%	PCARRD 1988
Pineapple	86%	PCARRD 1988
Coffee	6%	Purdue University Center for New Crops and Plant Products 2006
Mango	82%	PCARRD 1988
Tobacco	10%	standard tables on food and feed composition
Abaca	10%	standard tables on food and feed composition
Rubber	15%	Pratummintra et al. 2002
Cacao	4%	Purdue University Center for New Crops and Plant Products 2006
Cassava	63%	PCARRD 1983, IRRI 1983
Sweet potato	66%	PCARRD 1983, IRRI 1983
Peanut	9%	Bell et al. 1994
Mongo	10%	standard tables on food and feed composition
Onion	89%	standard tables on food and feed composition
Garlic	61%	standard tables on food and feed composition
Tomato	94%	IRRI 1983
Eggplant	92%	standard tables on food and feed composition
Cabbage	92%	standard tables on food and feed composition
Citrus (Calamansi)	92%	PCARRD 1988

[1] standard tables on food and feed composition were compiled from Watt and Merrill (1975), Löhr (1993) and Souci et al. (2000)

For annual crops, $ANPP_h$ was calculated using harvest indices and the formula: $NPP_h = \frac{H}{hi}$ (details see above). The HI values for the most important crops were gathered through an extensive literature review. In general, crop breeding aims to increase the commercially useful parts of the plant. This can be achieved by either increasing the plants total biomass or by increasing its HI (Evans 1993). The increase of the HI through breeding is well documented for temperate cropping systems (Krausmann 2001). A model assumption on the development of the HI of rice – the most important staple crop in the Philippines – was developed from various sources (IRRI 1983, Evans et al. 1984 and Peng et al. 2000) and statistical data (Philippine Rice Research Institute 1997 and IRRI 2006).

Table 12 Availability of harvest statistics in four selected years

FAO Crop Type Code I	**1910**	**1939**	**1970**	**2000**
C	Rice	Rice	Rice	Rice
C	Corn	Corn	Corn	Corn
O	Coconut	Coconut	Coconut	Coconut
S	Sugarcane	Sugarcane	Sugarcane	Sugarcane
F		Banana	Banana	Banana
F		Pineapple	Pineapple	Pineapple
Oth		Coffee	Coffee	Coffee
F		Mango	Mango	Mango
Oth	Tobacco	Tobacco	Tobacco	Tobacco
FI	Abaca	Abaca	Abaca	Abaca
Oth		Rubber	Rubber	Rubber
Oth		Cacao	Cacao	Cacao
RT		Cassava	Cassava	Cassava
RT		Sweet potato	Sweet potato	Sweet potato
N		Peanut	Peanut	Peanut
P		Mongo	Mongo	Mongo
V		Tomato	Tomato	Tomato
V				Onion
V				Garlic
V				Eggplant
V				Cabbage
F				Citrus (Calamansi)
				Other fruit crops
				Other Non-Food, Industrial and Commercial Crops
				Other Vegetables, Root Crops and Tubers
n	**6**	**17**	**17**	**25**
share production 1910 crops	100%	97%	95%	89%
share production of 1939/70 crops		100%	100%	99%
share area of 1910 crops	100%	93%	92%	86%
share area of 1939/70 crops		100%	100%	97%

Shares of the crops already reported earlier in the respective current recent years are shown in the lower part of the table. FAO crop type codes: C…Cereals; O…Oil bearing crops; S…Sugar crops; F…Fruits; Oth…Other crops; FI…Fibres; RT…Roots and tubers; N…Nuts; P…Pulses; V…Vegetables

In general, there was a strong increase in HI from the start of the IRRI rice breeding program in 60s to the mid-80s. After that, a leveling off has been observed (Peng et al. 2000). For corn, the second important staple, less research on HI in tropical condition exists; therefore, I had to use a cruder assumption. Literature (IRRI 1983, Johnson et al. 1986 and Jiang et al. 1999) suggests only a slight increase in HI in tropical corn due to modernized agriculture. Other main crops that were assumed to have an increase in HI over time are cassava and sweet potato (IRRI 1983, Kawano et al. 1998 and Hillocks et al. 2002). No development in HI could be found in the main cash crops - coconut, sugarcane and banana (IRRI 1983, Fageria 1992, De Silva and De Costa 2004, Koopmans and Koppejan 1998 and McIntyre et al. 2003). Other HIs for less important crops were complied from (IRRI 1983, Jölli and Giljum 2005 and Krausmann, 2006, personal communication). Table 13 shows the used HIs at four points in time and names their main sources.

Table 13 Harvest indices used in this study for selected years and main sources

Crop	1910	1940	1970	2000	Sources
Rice	0.36	0.37	0.39	0.48	IRRI 1983, Evans et al. 1984, Peng et al. 2000, Philippine Rice Research Institute 1997, IRRI 2006
Corn	0.30	0.30	0.31	0.39	IRRI 1983, Johnson et al. 1986, Jiang et al. 1999
Sugarcane	0.63	0.63	0.63	0.63	IRRI 1983, Koopmans and Koppejan 1998, De Silva and De Costa 2004,
Banana	0.33	0.33	0.33	0.33	Jölli and Giljum 2005, McIntyre et al. 2003
Pineapple	0.50	0.50	0.50	0.50	Jölli and Giljum 2005
Tobacco	0.25	0.25	0.25	0.25	Krausmann, 2006, personal communication
Abaca	0.10	0.10	0.10	0.10	Own assumption
Cacao	0.11	0.11	0.11	0.11	IRRI 1983
Cassava	0.35	0.46	0.56	0.64	IRRI 1983, Kawano et al. 1998, Hillocks et al. 2002
Sweet potato	0.50	0.61	0.70	0.70	IRRI 1983, Hillocks et al. 2002
Peanut	0.33	0.33	0.33	0.41	Bell et al. 1994, Jölli and Giljum 2005
Mongo	0.32	0.32	0.32	0.32	Krausmann, 2006, personal communication, Jölli and Giljum 2005
Onion	0.33	0.47	0.62	0.67	Jölli and Giljum 2005, own assumption
Garlic	0.67	0.67	0.67	0.67	Jölli and Giljum 2005
Tomato	0.50	0.50	0.50	0.50	Jölli and Giljum 2005
Eggplant	0.67	0.67	0.67	0.67	Jölli and Giljum 2005
Cabbage	0.67	0.67	0.67	0.67	Jölli and Giljum 2005
Citrus (Calamansi)	0.33	0.33	0.33	0.33	Jölli and Giljum 2005
Other fruit crops	0.33	0.33	0.33	0.33	average value of fruit crops
Other Non-Food, Industrial and Commercial Crops	0.50	0.50	0.50	0.50	average value of the respective crops
Other Vegetables, Root Crops and Tubers	0.60	0.60	0.60	0.60	average value of the respective crops

On annual cropland, the whole aboveground biomass of the commercial plant calculated via the HI was considered as societal harvest. For crop residues, the following uses were distinguished: feed for livestock, fuel, burned on site and decay on site. Assignment to these uses was only possible with very rough factors derived from Palacpac (1994), Mendoza and Samson (1999), Samson (2001) and own estimates. In general, rice straw was the most important item in this category. A change from its use as fodder for working animals (mainly carabaos) ntowards on site burning (no societal use) can be observed. This is due to the ongoing mechanization of agriculture (Mendoza and Samson 1999). The energetic use of rice straw as fuel is still not widespread compared to other countries (Yevich and Logan 2003). For corn, it is more common to let the stalks decay on site, to keep nutrients in the soils (Samson et al. 2001 and Gerpacio et al. 2004), while in lowland rice, high inputs of inorganic fertilizers are common today (Estudillo et al. 2001 and Tiongco and Dawe 2002). In sugarcane, on-site burning is common, while a certain share of the cane-tops is used as feed (Samson et al. 2001). Table 14 again gives the assumed factors, for four points in time.

Table 14 Assignment of crop by-products of three main annual crops

Crop	1910	1939	1970	2000
By-product societal use: **feed**				
Rice	33%	30%	23%	11%
Corn	26%	24%	22%	18%
Sugarcane	11%	10%	9%	8%
By-product societal use: **fuel**				
Rice	5%	10%	13%	12%
Corn	4%	8%	12%	19%
Sugarcane	2%	3%	5%	8%
By-product societal use: **other uses**				
Rice	12%	10%	6%	1%
Corn	10%	8%	6%	2%
Sugarcane	4%	3%	3%	1%
By-product **on site burned**				
Rice	35%	35%	42%	59%
Corn	15%	15%	15%	15%
Sugarcane	50%	50%	50%	50%
By-product **on site decay**				
Rice	15%	15%	17%	16%
Corn	45%	45%	45%	45%
Sugarcane	33%	33%	33%	33%

Sources: own estimate mainly based on: Mendoza and Samson 1999, Palacpac 1994, Samson et al. 2001, Gerpacio et al. 2004

For permanent crops, $ANPP_h$ consists of the commercial harvest and harvested by-products (leaves, trunks, etc.). Factors for the harvested by-products were derived for coconut because of its outstanding importance in this category (more than 90 percent of area and harvest throughout the period). It is important to note that the reported harvest for coconuts already contains by-products, i.e. the two coconut shells, while only the meat is usually commercially used in the form of copra, coconut oil, desiccated coconut, etc. Based on factors from Banzon (1982), Koopmans and Koppejan (1998), Samson (2001), Foale (2003), Chan and Elvitch (2005) and Mialet-Serra et al. (2005), the total harvested by-products were calculated and assigned to the following uses: societal use (fuel, other uses), on-site burning, and decay (the factors used are compiled in Table 15). The latter two were considered as backflows to nature. The category other uses contains ornamental use, commercial fertilizer and for building purposes (Banzon and Velasco 1982 and PCARRD 1985a, 1997). Coconut leaves, husks and shells constitute an extremely important supply of biofuel in the country (Samson et al. 2001 and Elauria et al. 2003).

Table 15 Factors used to calculate $ANPP_h$ of land planted with coconut (*Cocos nucifera*)

Factor	unit	1910	1939	1970	2000
Constant factors					
husks in reported harvest	%	41%	41%	41%	41%
shells in reported harvest	%	28%	28%	28%	28%
leaves per tree and year	t DM/ha/a	0.032	0.032	0.032	0.032
trunk increment per tree and year	t DM/ha/a	0.006	0.006	0.006	0.006
trees per ha	ha^{-1}	130	130	130	130
Variable factors					
share of leaves and trunks as fuel	%	20%	24%	29%	52%
share of husks as fuel	%	30%	33%	36%	40%
share of shells as fuel	%	70%	76%	83%	89%
share husks backflow	%	65%	60%	55%	50%
share shells backflow	%	25%	19%	12%	6%
share husks and shells other uses	%	5%	6%	7%	7%

Sources: own estimate mainly based on Banzon and Velasco 1982, Koopmans and Koppejan 1998, Samson et al. 2001, Foale 2003, Chan and Elevitch 2005, Mialet-Serra et al. 2005

Biomass grazed by livestock

Livestock is basically used as working animals (draft power) or for food (meat/milk/egg) production. In both cases, feed consumed by the animals is considered appropriated by the societies who own them. The compartment of $ANPP_h$ described here refers to biomass – mostly roughages – grazed by domesticated animals. Feed consumed by these animals that stems from commercial feedstuff and crop residues is already accounted for under agricultural crop harvest. The basic approach used to arrive at an estimate of the amount of biomass grazed, was to calculate the so-called “grazing gap”; i.e. the total livestock feed demand minus the above-mentioned feed components as described in Haberl et al. (2007a). The calculated grazing demand was assigned to different land use categories grazed by livestock. For the calculation, I used feed demand values per animal head along with statistical data on livestock numbers. The latter exist for the Philippines from about 1908 onwards, however, there are several data gaps in terms of missing years and livestock species. Also, the data show inconsistencies, e.g. due to different estimation models. I established my livestock data set from a number of sources (Bureau of Commerce and Industry 1918, 1923, 1928, Division of Agricultural Economics 1954, Bureau of the Census and Statistics 1960, NSO 2005b, FAO 2004, L. Lapar, 2006, personal communication and Bureau of Agricultural Statistics, 2006, personal communication). Data gaps and obvious inconsistencies were filled using linear interpolation or correlating data on the missing species to existing data of other livestock species for the same year. Table 16 shows livestock head data for selected years.

Table 16 Livestock numbers in 1000 heads in the Philippines for selected years

	1910	**1925**	**1939**	**1955**	**1970**	**1985**	**2000**
Carabao	757	1 706	2 914	3 279	3 159[2]	2 983	3 024
Cattle	270	917	1 349	806	1 679	1 786	2 479
Pigs	950[1]	2 142[1]	4 349	5 289	6 456	7 304	10 711
Goats	175[1]	395[1]	402	459	772	2 191	3 151
Sheep	25[1]	25[1]	25[1]	16	28	30	30
Horses	143	294	340	208	295	186	230
Poultry	6 796[1]	15 318[1]	26 099	46 313	59 272	57 560	124 929

Sources: Bureau of Commerce and Industry 1918, 1923, 1928, Division of Agricultural Economics 1954, Bureau of the Census and Statistics 1960, NSO 2005b, FAO 2004;
[1] estimates for missing data based on correlation to existing numbers on other species;
[2] own estimate arrived at via linear interpolation since the official numbers in that period are obviously inconsistent (L. Lapar, 2006, personal communication)

Feed demand for cattle and carabao was calculated with a dynamic model that relates feed intake to average carcass weight and average milk yield (Haberl et al. 2007a and Krausmann, 2006, personal communication). Data on carcass weight and milk yield were obtained from FAO 2004. The assumptions of the model yielded the following equations:

$$\text{Feed intake}_{\text{milk}} \text{ [kgDM/head/day]} = 0.00155 * \text{milk yield [kg/head/yr]} + 4.8375$$

$$\text{Feed intake}_{\text{weight}} \text{ [kgDM/head/day]} = 0.036361 * \text{carcass weight [kg/animal]} + 1.702006$$

These equations give different estimates of daily dry matter feed intake. In the calculation, the average value of the two values is used. For hogs and poultry, the methodology following Haberl et al. (2007a) was applied, using efficiency factors (feed demand per kg meat or egg output; Krausmann, 2006, personal communication). Meat and egg production were again taken from FAO 2004, before 1961, constant feed demand per animal was assumed. Wirsenius 2000 gives factors of 5 kg feed intake per kg pork production, 3 kg feed intake per kg egg production and 4.3 kg feed intake per kg poultry meat production for the Philippines. I calculated feed demand values per head and day for pigs and poultry, using these factors and the production data from the FAO database. For cattle, carabao, pigs and poultry, feed demand per head was calculated dynamically on a yearly basis from 1961 onwards as just described. For the calculation, I used simple model assumptions (linear interpolation between different points in time) fitted with the values on the development feed demand. The results of these model assumptions corresponded reasonably well with the actual calculated values. Before 1961, input data for the dynamic calculations were lacking. I assumed feed demand per head to have been constant before 1961, based on the fact that modernization of agriculture in the Philippines started only in the 1960s (e.g. Kerkvliet 1991, Khush 2001 and Evenson and Gollin 2003). Feed demand Per head for livestock species of minor importance (goats: 1 kg t DM/day, sheep: 1 kg t DM/day, and horses: 1 kg t DM/day were taken from (Wirsenius 2000) and kept constant over the whole period. The values of this described model were cross checked with country specific literature (PCARRD 2003b, 2003a and Lapar and Jabbar 2003) and proved to fit well. Table 17 presents the values used for my assumption on feed demand; the development between two data points was filled with linear interpolation.

Table 17 Feed demand in kg DM/day and its development over time for major livestock species

	1910	**1970**	**1988**	**1999**	**2004**
Cattle/Carabao	6.50	6.50	7.00	9.00	9.00
	1910	1960	1985	1993	2001
Pigs	0.533	0.533	0.800	1.260	1.320
	1910	1967	1987	2004	
Poultry	0.030	0.030	0.077	0.090	
	1910	2003			
Goats	1.00	1.00			
Sheep	1.00	1.00			
Horses	10.00	10.00			

Source: own estimate, see text

Data on market feed were taken from FAO (2004). Before 1961, market feed was assumed to be correlated to feed demand of non-grazers with a factor derived from the FAO data from the 1960s on. Statistical data on commercial crops reveals that growing of specific fodder crops is not common in the Philippines (with the possible exception of yellow corn, which is however not separated from corn for human consumption in statistics). Therefore, to arrive at an estimate of the "grazing gap", I subtracted the total market feed and the by-products of annual crops allocated as animal feed from the total feed demand. Market feed is assumed to be fed to non-grazers like hogs and poultry. If in a certain year the supply of market feed is larger than the demand of this group, the remaining part is considered to be fed to grazers. This amount of market feed fed to grazers is then multiplied by 1.5 to consider its higher nutritive value over roughages (Krausmann, 2006, personal communication). If the feed demand of non-grazers is lower than available market feed in one year, the gap is no longer accounted for since this group does not usually feed on roughages but is commonly fed with household wastes that are already considered as $ANPP_h$ in other parts of the calculation.

The total grazing demand was allocated to the following land use categories: other farmland, grassland, brushland, permanent cropland and open forest land, in accordance to the area of the respective category and with additional weight factors of 2, 1, 1, 1 and 0.5, respectively. Other farmland was weighted higher due to its physical proximity to the on farm animals. The largest share of livestock (especially grazers) are/were kept backyard on farms, often as working animals (see e.g. data in NSO 2005a). Open forest land can be grazed, since it is considered to have a continuous grass cover (NAMRIA 2004). It was weighted lower because it can be more remote and harder to access for livestock. Note that official Philippine statistics commonly do not have a category of pasture land. The Censuses of Agriculture give a category of "land under permanent meadows/pastures", but its definition is not clear in early years and its importance is relatively low (about 2 percent of total land area, declining to about 0.4 in the last two censes). The creation of improved sown and fertilized pastures is proposed in a number of publications, but such pastures not yet hold a relevant share in Philippine grasslands (e.g. Batcagan 2000).

Manure as a backflow to the ecosystems was calculated with crude factors from: 35% of the dry matter feed intake of carabao and cattle was considered manure, as were 25% of intake of goats, sheep and horses (Haberl et al. 2007a)Two thirds of this manure is considered on-site backflow where the grazing occurred and has no further societal use, the remaining third can be used as fertilizer on cropland.

Wood harvest

Wood harvest is another important category of societal biomass appropriation. Wood can be harvested to be used as wood products (denoted as industrial wood harvest) or as fuel (wood fuel harvest). In both cases all aboveground biomass killed during the extraction of wood is considered $ANPP_h$, whether or not it is removed from its original site.

Data on industrial wood harvest before 1960 were attained from a number of sources (Bureau of Commerce and Industry 1918, 1923, 1928, Division of Agricultural Economics 1954, Bureau of the Census and Statistics 1960 and Dy 1998). From 1961 onwards, FAO data were used (FAO 2004). The latter were compared to national statistical data (NSO 2005b) and found to have about the same magnitude, but were based on clearer definitions. Data were converted from board feed to cubic meter, where necessary using a factor of 0.00236. Values of roundwood under bark in cubic meter were converted to tons dry matter over bark using a bark factor of 0.9 (Haberl et al. 2007a) and an average density of 0.594 t DM m^{-3} (calculated from Magcale-Macandog et al. 2005). Total biomass fellings were calculated via the so-called recovery rate. Total biomass fellings include biomass killed during logging operations staying on site and removals from the forest. The recovery rate is the ratio of removals to total fellings. For industrial wood harvest a recovery rate of 46 percent is assumed (Pulkki 1997). The felling losses are assigned to: backflow to nature, on site burned, use as fuel. This allocation follows Magcale-Macandog and Nishioka (2000) and Enters (2001) and assumes an increase of the use as fuel over time. Factors used are reported in Table 18. Industrial wood harvest was allocated to closed forest land. From the 1960 onwards a certain share was also allocated to open forests, as closed forests became more and more scarce.

Table 18 Factors used for calculating ANPPh related to industrial wood harvest

Constant factors	**Unit**	**Value**			**Source**
avg. wood denisty	t DM m^{-3}	0.59			Magcale-Macandog et al. 2005
bark factor	%	90%			Haberl et al. 2007a
Recovery rate	%	46%			Pulkki 1997
Variable factors **fate of residues**	**1910**	**1950**	**1970**	**2003**	
used as fuel	0%	0%	10%	30%	Magcale-Macandog et al. 2005, Enters 2001
on site decay	70%	70%	60%	50%	
on-site burned	30%	30%	30%	20%	

The quality of the data on the harvested volume of wood fuel is quite unsatisfactory. Numbers on total nationwide wood fuel consumption are usually calculated from per capita/per household values (PCARRD 1985b and Rebugio et al. 2000). For the time series, I used data supplied by the FAO for the time after 1961. This represents an estimate of how much wood was removed with the primary purpose of being used as fuel. Crop by-products and residues from industrial wood were not considered in this estimate, and the FAO model takes population development, uses of other fuels, forest area, etc. into account (Whiteman et al. 2002). For the years 1996 to 2001, the FAO reports a much higher wood fuel production. These figures does not stem from the mentioned model but from data reported by the Philippines. Consultation of the literature (Bhattarai 1997, Rebugio et al. 2000 and Elauria et al. 2003) revealed that the figures reported by the FAO from 1996 to 2001 were obviously an estimate of total biofuels consumed, including e.g. agricultural by-products used as fuel. Since those by-products are already accounted for as $ANPP_h$ in other parts of the calculation, the numbers of the new FAO model were used, and linear interpolation was applied for the time between 1996 and 2001. Before 1960, wood fuel demand was calculated via per capita values due to the lack of reliable statistical data sources. These values were derived from PCARRD (1985b), Bensel and Remedio (1993), Bhattarai (1997) and Rebugio et al. (2000); the same bark factor and average density as for industrial wood are used and the recovery rate was assumed to be 69 percent (Erb, 2006, personal communication). The wood fuel harvest is assigned to the land uses with respect to their area share in total land use: forest land (four subcategories) and brushland with a lower weighting factor, reflecting that it contains some woody elements, suitable for marketable wood fuel, but not as much as forests. Mangroves are weighted somewhat higher since they are a traditional common source of wood fuel, also due to their proximity to densely populated coastlines (Kolb 1942, Wernstedt and Spencer 1967, Primavera 2000).

Human-induced fires

Fire has been used as a management tool by humankind since its very beginning and has been used for a broad variety of purposes. In my calculation, I also consider biomass burned in human-induced fires as part of $ANPP_h$. Unfortunately, the data situation on this item is very limited for the Philippines; therefore, some model assumptions had to be made. I distinguish between the following components of human-induced fores:

- fires on grasslands;
- fires on other land use types with other origin than slash and burn practices; and
- fires originating from slash and burn/swidden agriculture practices (not included in the final results unless noted otherwise, due to low data quality; details see below).

All authors agree that grassland areas are commonly burned. Often fire is used as a tool to keep areas open for grazing, but there also exist other causes of fires, e.g. burning by accident (Wibowo et al. 1996, Pasicolan et al. 1996, Magcale-Macandog et al. 1998 and Menz et al. 1998). *Imperata cylindrica* grasslands on degraded lands often develop a fire climax in Southeast Asia (Garrity et al. 1996 and Wibowo et al. 1996). I assume that, on average, grasslands are burned every three years (Pulhin and Lasco 1999 and Magcale-Macandog, 2006, personal communication). Using IPCC values for aboveground standing biomass volume and combustion factor (i.e. the share of aboveground biomass burned; IPCC 2006), I calculated the average burned biomass on grassland per year (see Table 19).

The same basic approach was applied to account for other human-induced fires, excluding those originating from slash and burn agriculture. Data on the average yearly area burned by these fires are very rare and unreliable. For this study, a rough estimate of 10 000 ha burned area per year was used (derived from Goldammer 2002 and Ganz 2002). This assumption can be considered to be a conservative estimate and is kept constant over time although I am aware that the area burned each year is subject to strong yearly variations. The amount of burned biomass was calculated using the latest IPCC aboveground biomass stock numbers and combustion factors (IPCC 2006, these values were cross checked with Lasco et al. 2004b). Table 19 compiles the values used. The area burned was assigned to the land uses, considering their share of total land area: forest land, brushland, other farmland, settlement and infrastructure area.

Table 19 Aboveground biomass and combustion factors for different land uses

Land use	Average aboveground Biomass in t DM/ha	Combustion Factor	Source
Closed Forests	330	36%	IPCC 2006
Open Forests	165	55%	IPCC 2006
Mangrove Forests	247	36%	IPCC 2006
Annual Crops	10	83%	IPCC 2006
Permanent Crops	165	59%	assumed to be same as open forests
Other farmland	70	72%	assumed to be same as brushland
Grassland Area	6.2	83%	IPCC 2006
Brushland	70	72%	IPCC 2006
Settlement and Infrastructure Area	23	72%	assumed to be a third of brushland

Details see text

Shifting cultivation has been a major form of human subsistence for a long time. Ruthenberg 1980 (as cited in Lauk 2006) gives this basic definition:

„Shifting Cultivation is the name we use for agricultural systems that involve an alternation between cropping for a few years on selected and cleared plots and a lengthy period when the soil is rested. Cultivation consequently shifts within an area that is otherwise covered by natural vegetation."

There is a long history of shifting cultivation, swidden agriculture or slash and burn in the Philippines. It is believed that before the arrival of the Spanish, and well into their reign, it was the main mode of subsistence for the majority of the population (Corpuz 1997) and remained so for a relevant share of the population until recently (Olofson 1981). However, no reliable data on the extent of shifting cultivation exists. A distinction has to be made between original shifting cultivators and "shifted cultivators" (Myers 1993), i.e. farmers who have practiced permanent agriculture – usually in the lowlands – before and who were forced to migrate to lands that require swidden practices. The latter often lack the knowledge on adequate farming practices and/or legal land titles and can cause serious degradation to their environments (Pulhin 1996 and Lawrence 1997). In general, the average fallow period varies a lot depending on the swidden system, the land quality, and the pressure on land resources. Over time, a decrease in the length of the fallow period is described in many cases as population increases and migrants practice unsustainable swidden and often push back indigenous systems to remote areas (Olofson 1981, Rice 1981, Collins et al. 1991, Lawrence 1997 and Lauk 2006).

Due to the lack of data on the scope and development of areas affected by slash and burn, it was not possible to integrate this important phenomenon into my time series calculation. However, to give an idea, I present a rough estimate of what could be its effect on HANPP. This simple estimate is based on: an area estimate on the extent of swidden agriculture in the Philippines in 1966 from Spencer cited by Olofson (1981). Spencer estimates that 1966 about 3.9 Mha were in the state of regenerating fallow while 0.9 Mha were under some form of cultivation. I calculate the area burned every year as total fallow area divided by the average fallow period. My estimate for the average fallow period in 1966 in 10 years, which is a very rough estimate based on e.g. Rice (1981), Collins et al. (1991) and Lawrence (1997). Further, two crude assumptions are made for 1910 and 2003, the starting point and end point of my time series. I assume that the swidden area was still larger in 1910, as permanent agriculture was still less widespread. Due to the lack of other data, Spencer's value was multiplied with 1.5 and the length of the fallow period was set at 12.5 years for 1910. For 2003, I assumed that the area had declined to half of the 1966 value and the average fallow period to only 7.5 years. To calculate the biomass burned through swidden fires, the following formula was used:

$$ANPP_{hsfire} = \frac{A_{sf}}{t_{fp}} * SB * CF$$

where
$ANPP_{hsfire}$…"harvested" aboveground biomass burned in swidden fires
A_{sf}…total Area under swidden fallow
t_{fp}…average length of the fallow period
SB…average standing biomass of the burned system
CF…combustion factor (share of biomass burned)

The values for standing biomass and combustion factors used are those reported in Table 19. Table 20 compiles the described input factors for swidden area and fallow period. Between two data points linear interpolation was applied. The swidden fires were assigned to the land uses: closed forests, open forests, other farmland and brushland in general according to their area. However, the category closed forests was weighted lower with a factor of only 0.2, because, in general, patches of land that had been cleared before (be it through as a previous swidden or logging) are preferred by traditional swidden agriculturists as well as "shifted cultivators" (Olofson 1981 and Kummer 1991).

Table 20 Input factors for my slash and burn estimate

	unit	1910	1966	2000
area under fallow	Mha	5.9	3.9	2
average fallow period	a	12.5	10	7.5

Details see text; note that direct effects of this practise on NPP are not considered; only if slash and burn agriculture results in land use changes the resulting NPP of the respective area will be different.

Additional data

I use the following additional data to discuss the results of my HANPP calculation in a broader context:

- Population data taken from different census years compiled in NSO 2005b and the development between these years from a project on historical population statistics by Jan Lahmeyer[13]. Projections for the years after the last population census in the year 2000 were again taken from NSO (2005b);
- GDP: Hooley (2005) gives an detailed historic reconstruction of Philippine GDP for the years 1902 to 1990 with omission of the years 1941 to 1949. I obtained data for the time period after 1990 from the UN statistical database (UN Statistics Division 2004);
- Consumption of inorganic fertilizers from 1961 onwards was taken from data provided by the FAO's statistical database (FAO 2004);
- Data on energy consumption was provided by Fridolin Krausmann (2006, personal communication), originating from IEA database from 1971 onwards and various historical sources before that year; and
- Data on biomass trade from 1961 onwards was again obtained from the FAO's statistical database (FAO 2005); data to give a rough estimate of the development before that year were taken from historical sources (Bureau of Commerce and Industry 1918, 1923, Kolb 1942 and Division of Agricultural Economics 1954).

[13] This project can be found online at http://www.populstat.info/, accessed November 15, 2006

Results

In this section, I present the results of my calculations and briefly discuss their implications. In general, I follow the order of the methodology part above. Results of the final HANPP calculation are presented, after showing results for its single components. In the beginning I present results for the development of land use.

Land Use

Figure 3 shows the development of land use in the Philippines from 1910 to 2003. As can be seen in Figure 3, forest cover in the Philippines declined rapidly over the last century. Farmland and secondary vegetation (grass- and brushland) seem to have replaced forests[14]. According to the latest data on forest area, the decline of forest area has more or less came to a halt in recent years[15]. Settlement and infrastructure areas increased over time, as did the fishpond area; the latter at the expense of the mangrove area (Primavera 2000). Relating to forest land, the decline was drastic for closed forest, while open forests increased somewhat in area. In the case of farmland, both annual and permanent crops increased, while other farmland (i.e. idle land) declined. Table 21 shows aggregated values for the four main land use categories for selected years.

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[14] At the turn of the 19th and 20th century, total forest cover is assumed has been 65% of the nation's total land area. However, this was not evenly spread. While densely populated area on Luzon and in the Visayas were deforested almost completely, the island of Mindanao was still heavily forested (the Spanish rule could never take control over the major parts of the island) (Bankoff 2006). Kummer (1992b) gives a description of how land use change to other land uses might occur over time. Most forest remaining by mid-century could be found in the uplands; migrants from overpopulated lowlands followed commercial logging operations and established upland farms. Kummer claims that upland agriculture of these migrants is kind of sedentary in most cases. However with degradation issues and insecure tenure, upland farms often become abandoned leading to secondary vegetation forms such as grass and brushland.

[15] Reasons for this could be the fact that remaining forests are usually found in steep remote areas, but also the effect of logging moratoriums, success of reforestation programmes and spontaneous tree planting by upland farmers (Pulhin et al. 2006).

Table 21 Summary of land use development in the Philippines relating to the 4 major land use categories for selected years

	1910	1925	1939	1955	1970	1985	2000
Forest land	18.9	17.9	16.1	13.6	9.9	7.5	7.1
Farmland	3.6	6.4	6.4	6.7	8.2	9.6	9.4
Grass- and brusland	7.0	6.4	6.8	9.0	11.0	11.9	12.3
Other land	0.3	0.4	0.4	0.5	0.7	0.8	1.0
Total	29.8	29.8	29.8	29.8	29.8	29.8	29.8

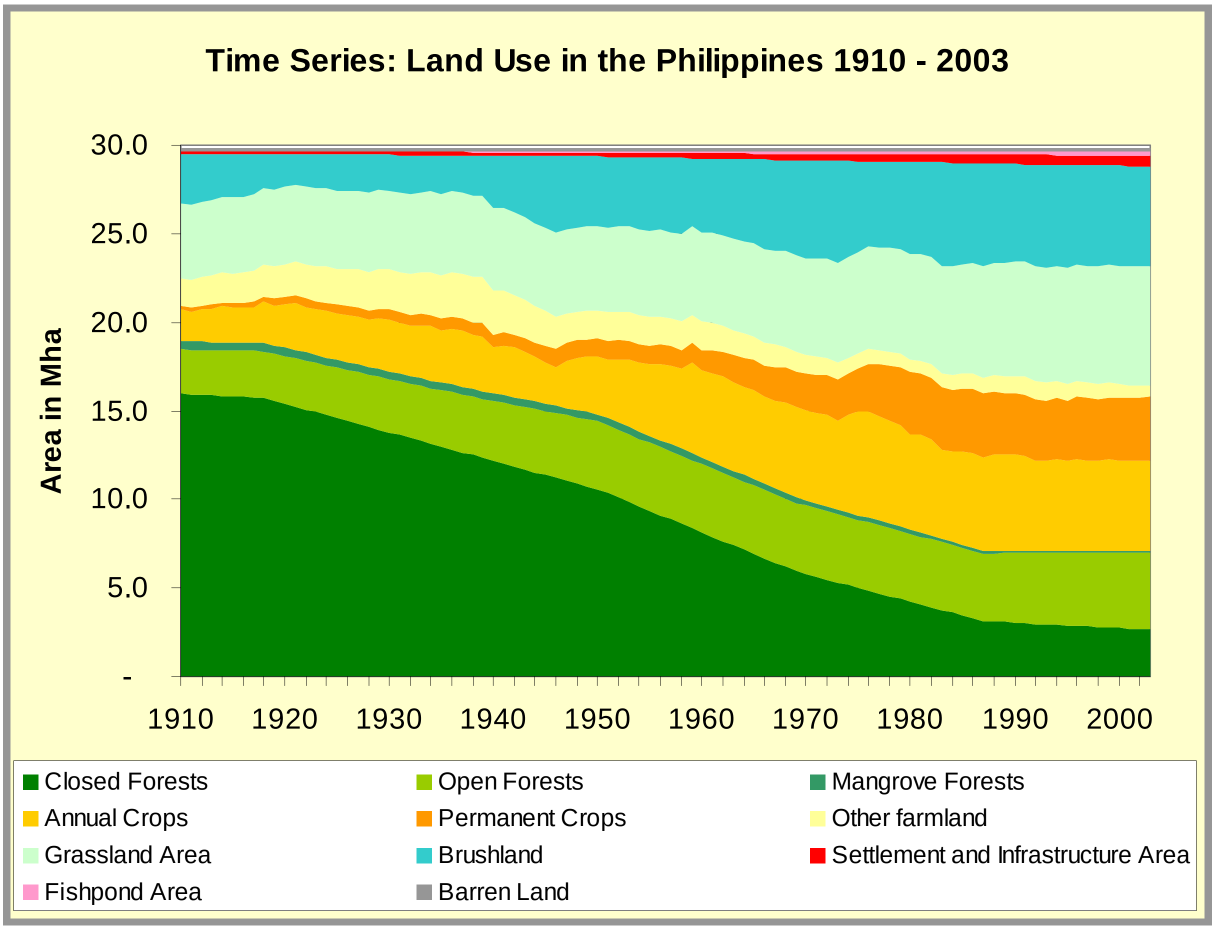

Figure 3 Development of land use in the Philippines 1910-2003

Figure 4 presents a possible scheme of occurring dynamics in land use change during the studied period. It has to be noted, however, that these dynamics mostly refer to processes in the nation's uplands were permanent agriculture with annual crops can hardly be practiced. In the lowlands, agriculture has evolved from crop rotation with longer fallow periods towards an intensified state with common multicropping facilitated by high inorganic fertilizer input and irrigation. Over the course of the 20th century, many of the remaining primary forests were cleared through logging operations, opening them up for migrants who were looking for land to cultivate. Because of the physiography of the land and insecure tenure, farms often had to be abandoned after a few cropping seasons. Depending on a variety of variables like the mentioned physiography, duration and intensity of previous use, and subsequent use as pasture, abandoned farmland turned into a) permanent grassland or b) went into succession towards brushland and secondary forest, if granted enough time of re-growth. As mentioned, permanent grasslands, commonly *Imperata* dominated, are usually heavily degraded and establish a fire climax society. Their rehabilitation into more productive forms of land use is posing a major challenge with the crucial importance of fire control (Wibowo et al. 1996 and Menz et al. 1998). Fallow periods before secondary forests, brushlands and grasslands, which were taken again under cultivation, became shorter over time and consequently, increased pressure on the land and increased amounts of degradation. Unsustainable upland farming practices of migrant swidden farmers often had the same effect. Agroforestry, the intercropping of tree species with annual crops, has been proposed as a way to improve land productivity and provide a sustainable livelihood for upland population (Menz et al. 1998 and Cramb 2001)[16].

Aboveground productivity of the potential vegetation ($ANPP_0$)

As mentioned, I use $ANPP_0$ data from the LPJ-DGVM model using a constant value of 11.65 t DM per hectare and year. This yields a yearly $ANPP_0$ of 347 Mt DM for the whole of the Philippines. Figure 5 shows the development of the distribution of $ANPP_0$ over the 4 different major land uses. Because $ANPP_0$ is assumed constant, this development reflects the development of the land uses.

[16] There is some indication of the success of such agroforestry practices (Chokkalingam et al. 2006), however, no relieable data on the actual aerial extent of agroforestry exists; therefore I could not include it in my land use time series. It could be included with farmland but also brushland or forest land (Pulhin et al. 2006).

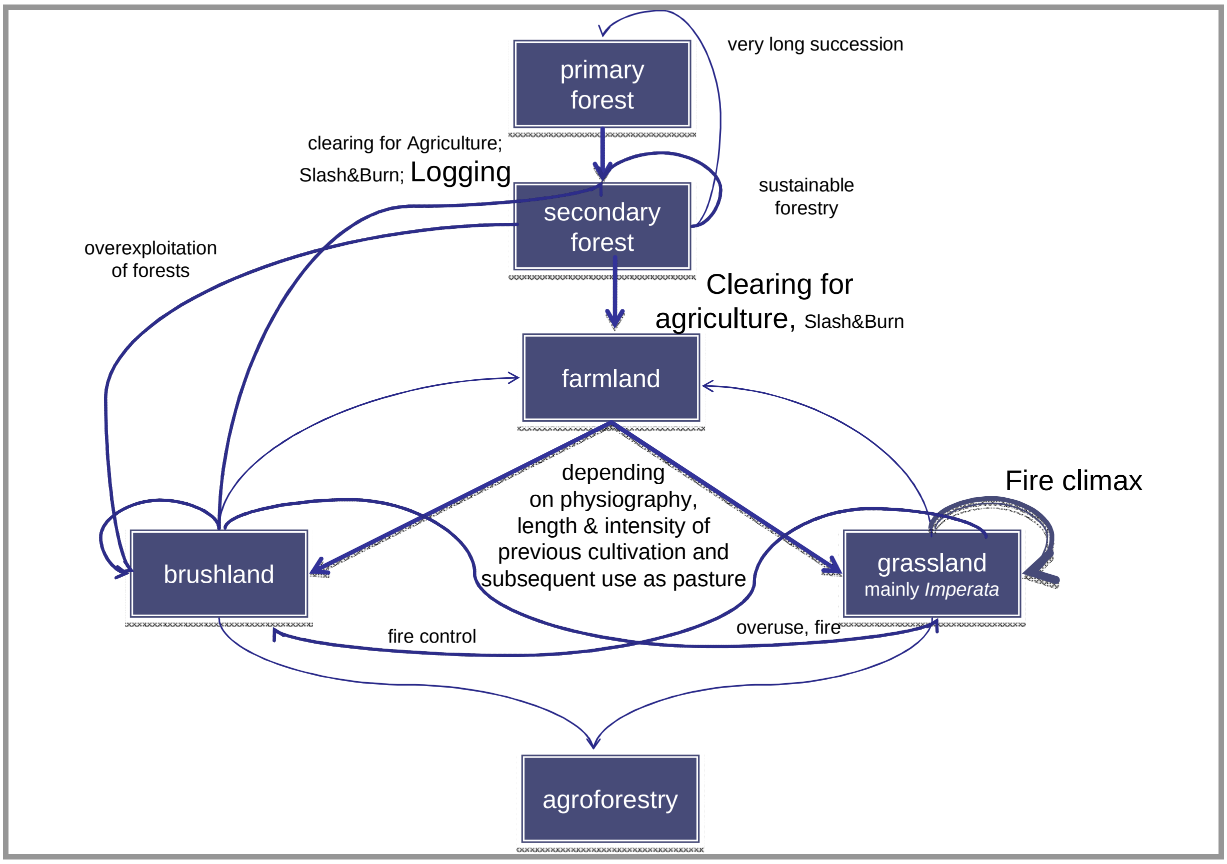

Figure 4 Land use dynamics in the Philippines, details see text

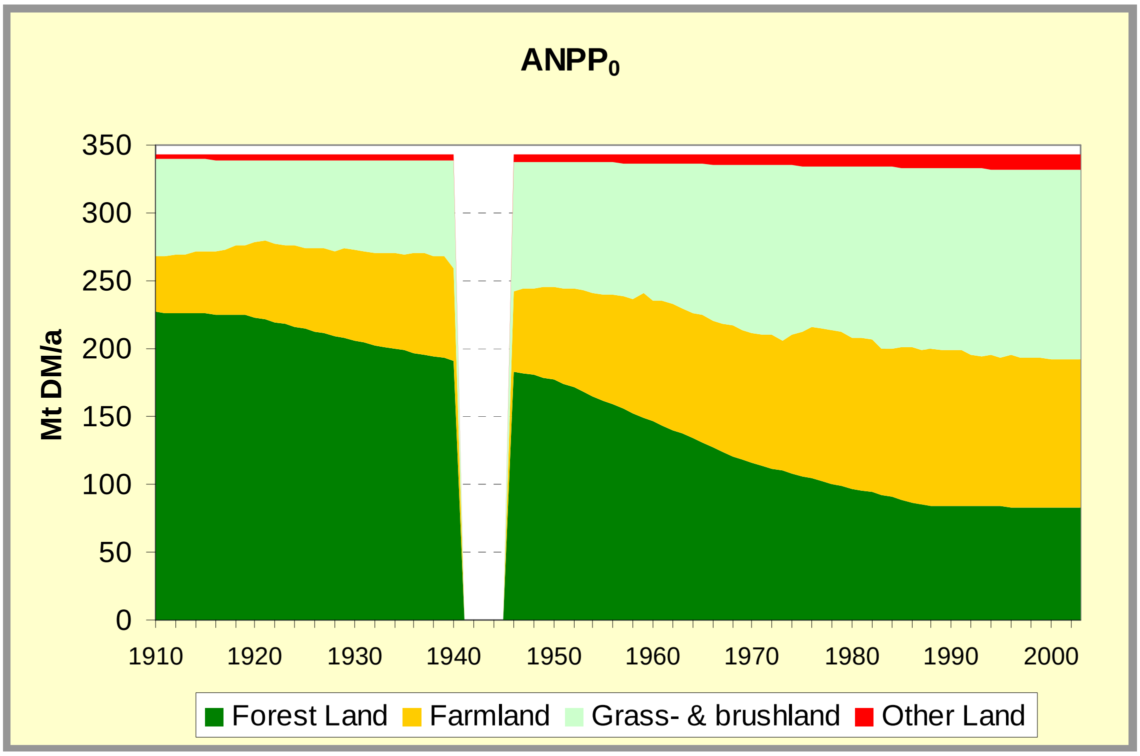

Figure 5 Development of $ANPP_0$ in the Philippines 1910-2003 on the 4 major land uses over time

Aboveground productivity of the actual vegetation ($ANPP_{act}$)

Figure 6 gives the absolute development of $ANPP_{act}$ in the Philippines from 1910 to 2003. Values for four selected years can be seen in Table 22.

Table 22 Development of $ANPP_{act}$ in the Philippine on the 4 main land uses in Mt DM/a for selected years

	1910	1925	1939	1955	1970	1985	2000
Forest land	218	205	184	153	110	81	76
Farmland	22	37	47	46	69	91	102
Grass- and brusland	51	45	47	65	80	84	85
Other land	1	1	1	1	1	2	2
Total	292	287	279	265	261	258	265
in % of $ANPP_0$	84%	83%	80%	76%	75%	74%	76%

The total value declined until the 1960s, when it stabilized and eventually increased again a bit in recent years. Looking at the $ANPP_{act}$ share of forest land, this dropped to about one third of its original value between 1910 and 2000, corresponding, in general, to the decline in forest area. $ANPP_{act}$ on farmland increases five-fold. It made up the largest share of the total value in recent years, contributing the most to the stabilization of the total value.

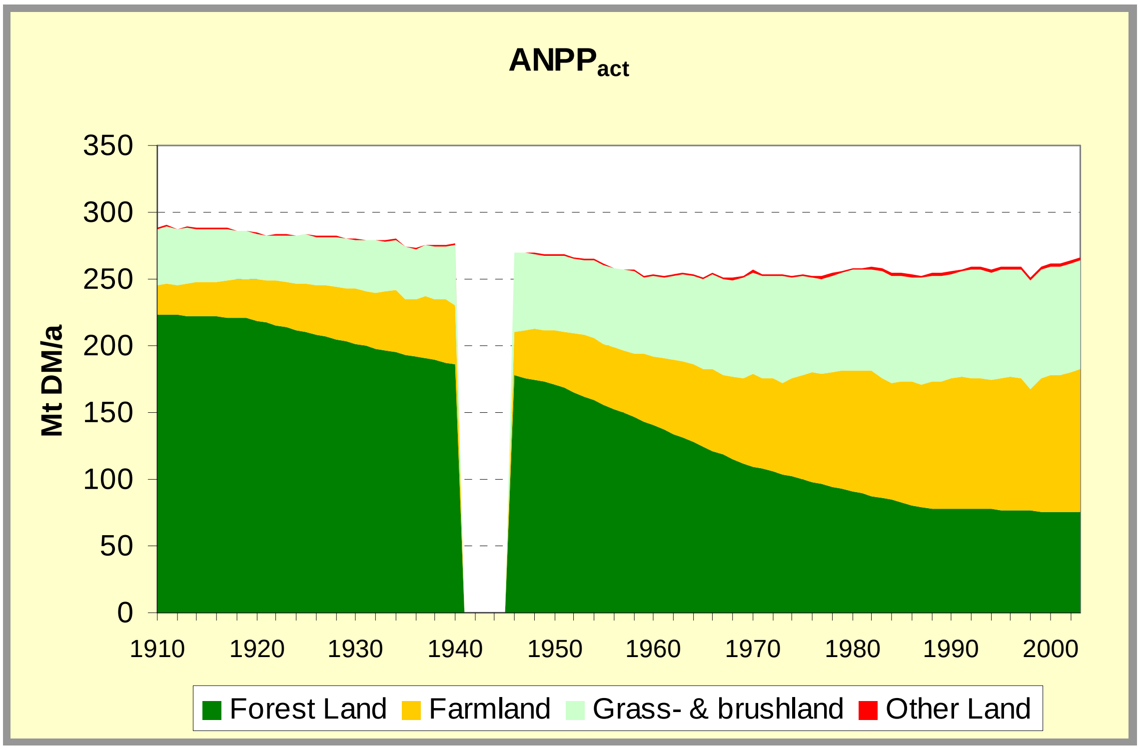

Figure 6 Development of $ANPP_{act}$ in the Philippines 1910-2003 on the 4 main land uses

Per hectare $ANPP_{act}$ for different land uses showed a more or less constant picture until about 1960 (see Figure 7). Thereafter, $ANPP_{act}$ on farmland increased strongly, from about 6 t DM per hectare and year to over 11 t DM/ha/a. $ANPP_{act}$ on forest land showed a slight decline as the relative share of open forests increased. On grass- and brushland, it was more or less constant throughout time; while $ANPP_{act}$ on other land increased due to the increase of settlement and infrastructure area (the other two subcategories – barren land and fishponds – have an $ANPP_{act}$ of 0).

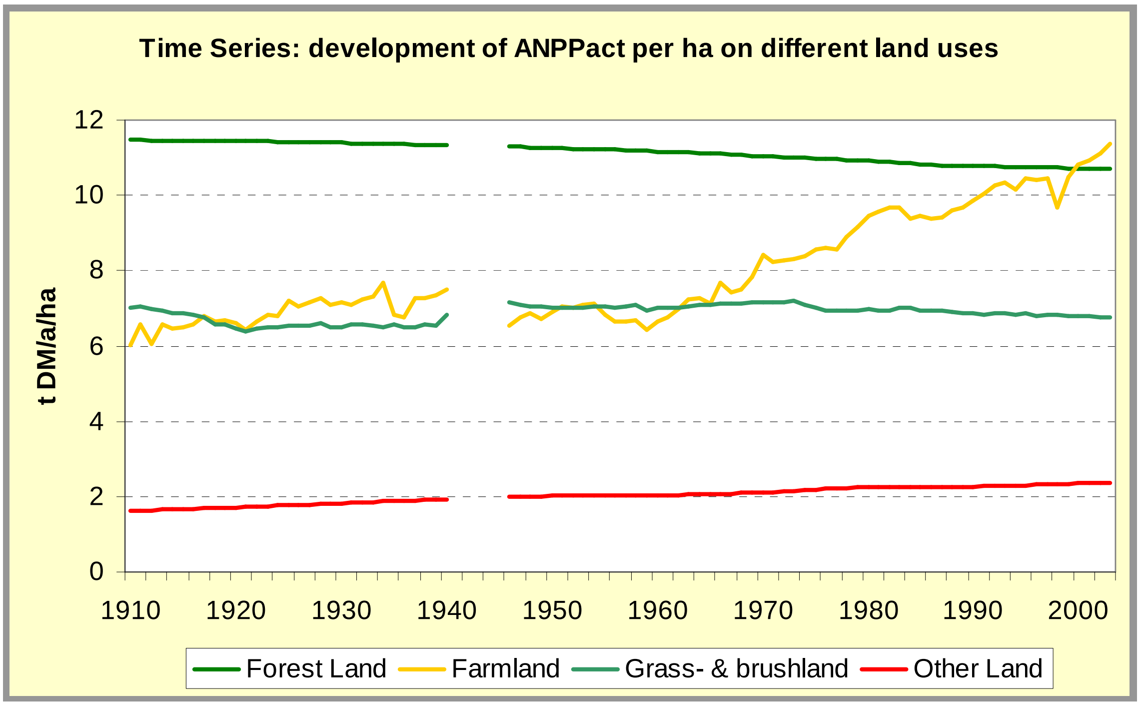

Figure 7 Development of $ANPP_{act}$ per hectare in the Philippines 1910-2003 for the 4 main land uses

$\Delta ANPP_{LC}$ is a measure of potential aboveground productivity foregone through human-induced land use change. It is defined as the difference of $ANPP_0$ and $ANPP_{act}$. Table 23 shows its values for selected years. While in the beginning of my time series, farmland and grass- and brushland both contributed the largest share, in recent years the lion's share of ANPP was "lost" on grass- and brushland. It is also interesting to see that, while the category other land only occupies a small share of the total area, it contributed almost the second highest share in $\Delta ANPP_{LC}$ in 2000.

Table 23 Absolute $\Delta ANPP_{LC}$ development in the Philippines on the 4 main land uses in Mt DM/a for selected years

	1910	1925	1939	1955	1970	1985	2000
Forest land	4	4	5	6	6	6	7
Farmland	20	23	28	32	26	21	8
Grass- and brusland	30	31	33	40	49	55	60
Other land	1	2	2	3	5	6	7
Total	55	59	68	82	87	88	82
in % of $ANPP_0$	16%	17%	20%	24%	25%	26%	24%

Aboveground biomass harvested by humans ($ANPP_h$)

I present biomass harvest following the four functional types outlined in the methodology part at first. After that, a synthesis of the obtained development of $ANPP_h$ values is provided.

Agricultural crop harvest

Total farmland increased from 3.5 Mha in 1910 to above 9 Mha during the 1970s and has stayed more or less constant since then[17]. Dry matter crop production increased more strongly due to increases in yield than due to increases in cropping area (Figures 8 and 9). Area of land under actual cultivation increased by a about a factor 4, as idle farmland declined. The staples rice and maize hold by far the largest share in annual cropland area, while coconuts almost completely dominated permanent cropland. Relating to production, the share of other annuals was higher. This is mainly to the high yields of sugarcane, an important cash crop in the country. In general, rice and corn are the most common staples, with rice dominating the lowlands and corn for human consumption commonly present in the uplands, often considered as "rice

[17] Kummer (1992b) gives a number of sources claiming the land frontier for arable land had been reached in the Philippines during the 1960s or 1970s. He claims that the concept of land frontier is kind of vague and cites an area of about 8.4 Mha from the Bureau of Soils (1977) that is claimed to be cultivatable without excessive input for land conservation. In his work, he predicts an increase in farm area during the 1980s – however when he wrote his work, the results of the 1991 Census of Agriculture were not published. While other farmland somewhat declined from the 1980 at the expense of cultivated land, total farmland stayed more or less constant and even declined a bit according to the latest census 2002 (NSO 2005a; compare Table 3). To what extent upland agriculture was covered in those censuses, especially farming without legal titles can not be assessed in this study.

of the poor" (Kolb 1942, Wernstedt and Spencer 1967 and Gerpacio et al. 2004). More recently, yellow corn has been used as commercial feedstuff in large amounts (Cardeans et al. 2005). Sugarcane and coconut are grown as the main cash crops. The fiber crop Abaca was of main importance well into the 20th century, but its popularity declined due to pest outbreaks and the introduction of artificial fibers (PCARRD 1977). Cash crops with increasing importance are fruit crops such as banana, pineapple and mango. Additional staples are roots and tubers like sweet potato and cassava. The share of these two crops in total crop production more than doubled from 1.25% in 1925 to 2.67% in 2000. Amongst the two, the share of cassava rose from 10% to 78%.

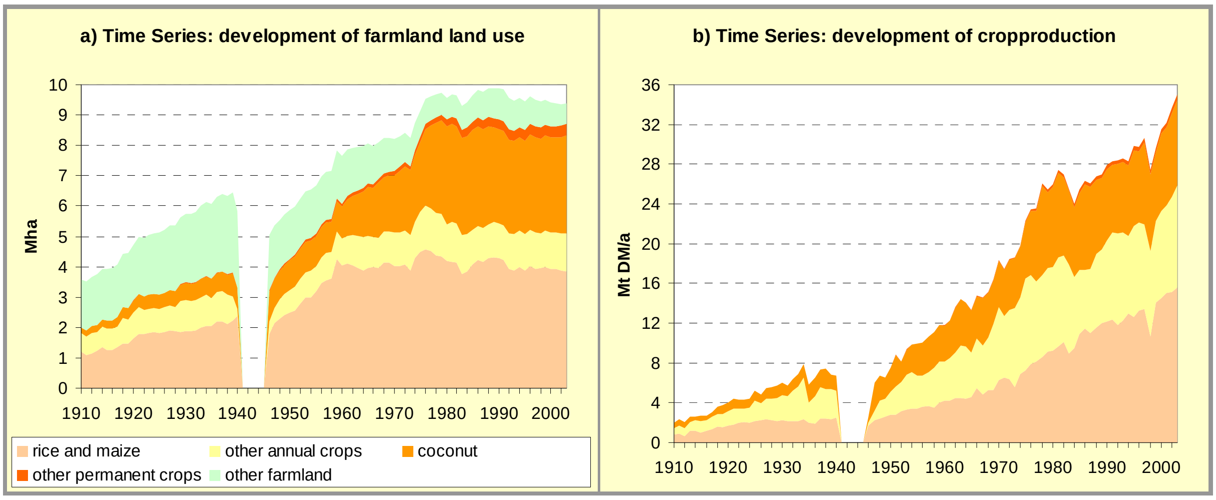

Figure 8 Development of (a) farmland area and (b) crop production in the Philippines 1910-2003

Yields increased considerably in annual crops, permanent crops showed a more erratic performance (Figure 9). Crop breeding, irrigation, inorganic fertilizers, pesticide use and improved farming techniques could be held responsible for the 4-fold yield improvement in rice and maize. Much of this occurred with the set off of the Green Revolution that was, in terms of yield improvement, by far most influential and successful in the rice sector. However, energetic output to input ratio declined through the increased use of fossil based energy. Kellman and Tackaberry (1997), citing a study by Freedman (1980), give numbers for this ratio of 13.84 in a traditional system and 2.91 in a Green Revolution system, respectively. This decrease in energetic return is typical in fossil fuel based agriculture. While in the agricultural mode of subsistence a ratio significantly greater than one is a necessity, since biomass provides virtually the entire energy base, this limitation is lifted in fossil-fuel based production, with its area independent energy source (see e.g. Fischer-Kowalski et al. 2007). An even stronger increase in average yields of other annuals also has to be accredited to the relative decline of the low yielding fibre crop abaca, next to the increase of high-yielding annual crops such as sugarcane and cassava (the latter is only included in reports from 1929 onwards).

It is interesting to observe how the processes determining HANPP on farmland change dramatically over time (Figure 10). In the beginning of my time series, HANPP was almost entirely controlled by foregone productivity, and biomass harvest played a minor role; over the studied period this has changed to the opposite. In recent years, the actual productivity approached the potential one and $ANPP_h$ more or less exclusively determines HANPP on cropland.

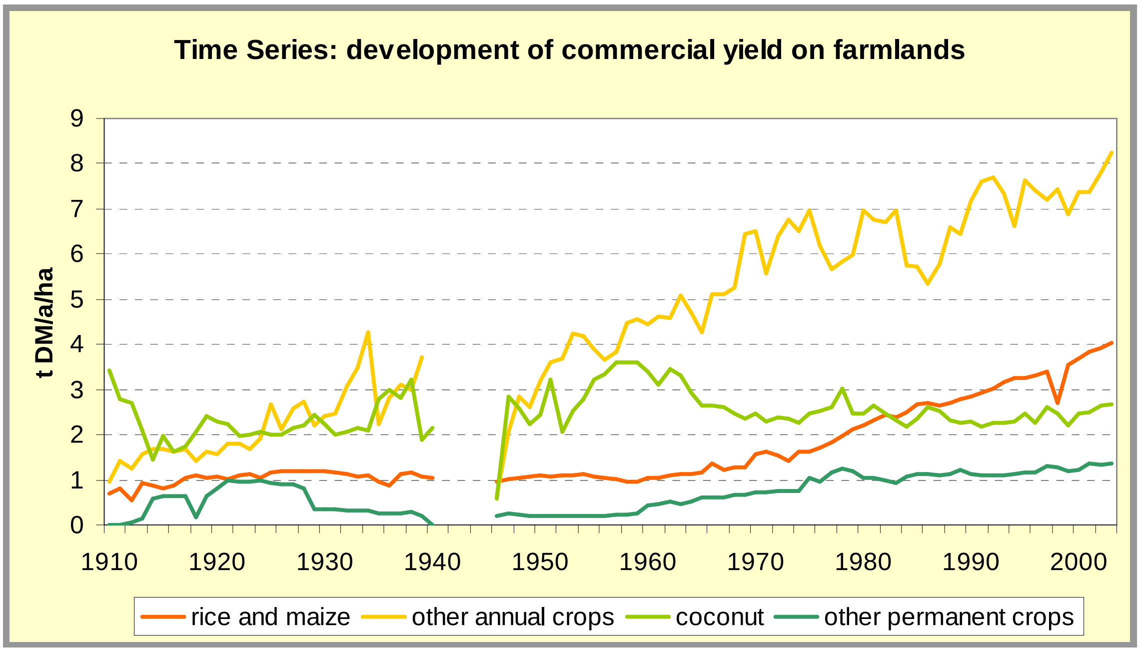

Figure 9 Development of average crop yields in the Philippines 1910-2003

In Figure 11, I show the absolute development of $ANPP_h$ on farmland presenting commercial harvest and the fate of by-products. Overall, $ANPP_h$ on farmland increased from only slightly over 5 Mt DM per year in 1910 to well over 70 Mt DM/a. The strongest increase can be seen in commercial harvest and in by-products used as fuel. Residues of coconuts such as leaves and the trunks make up the largest share in the latter category.

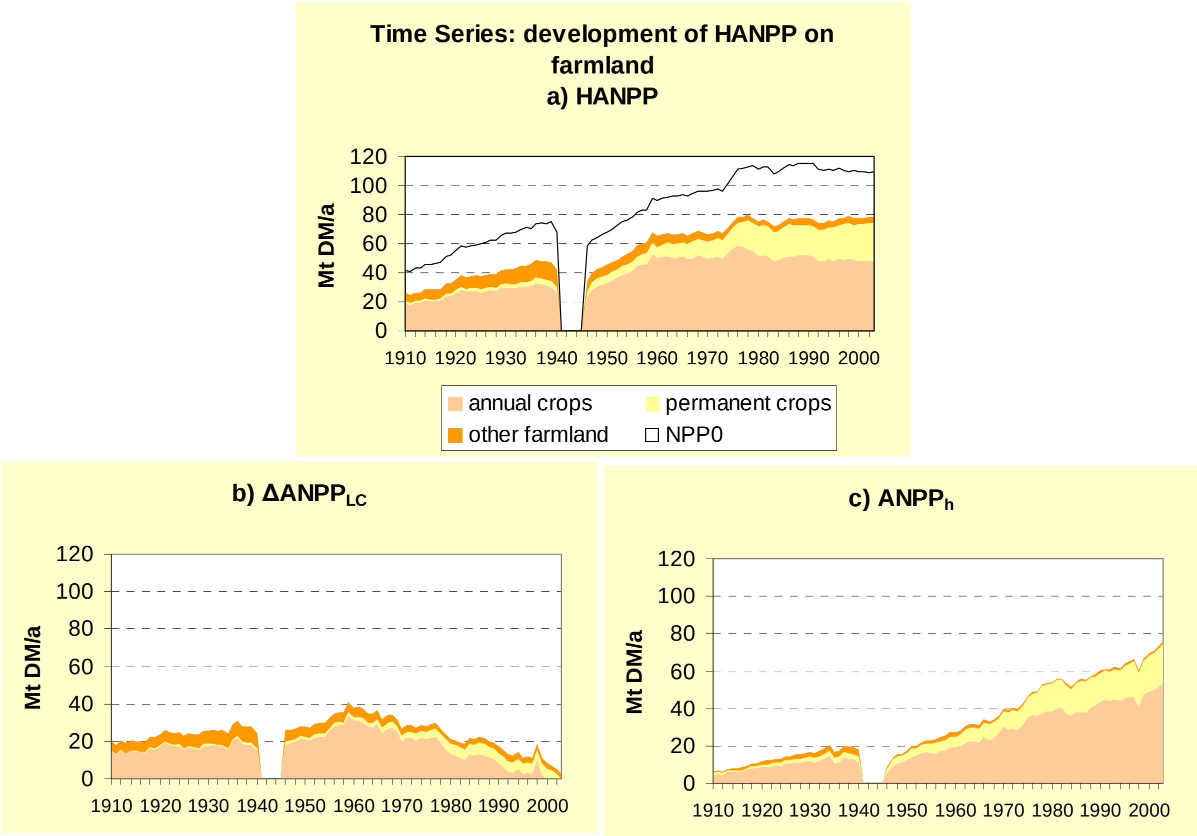

Figure 10 Development of (a) HANPP and its two constituting components (b) $\Delta ANPP_{LC}$ and (c) $ANPP_h$ on farmland in the Philippines 1910 – 2003

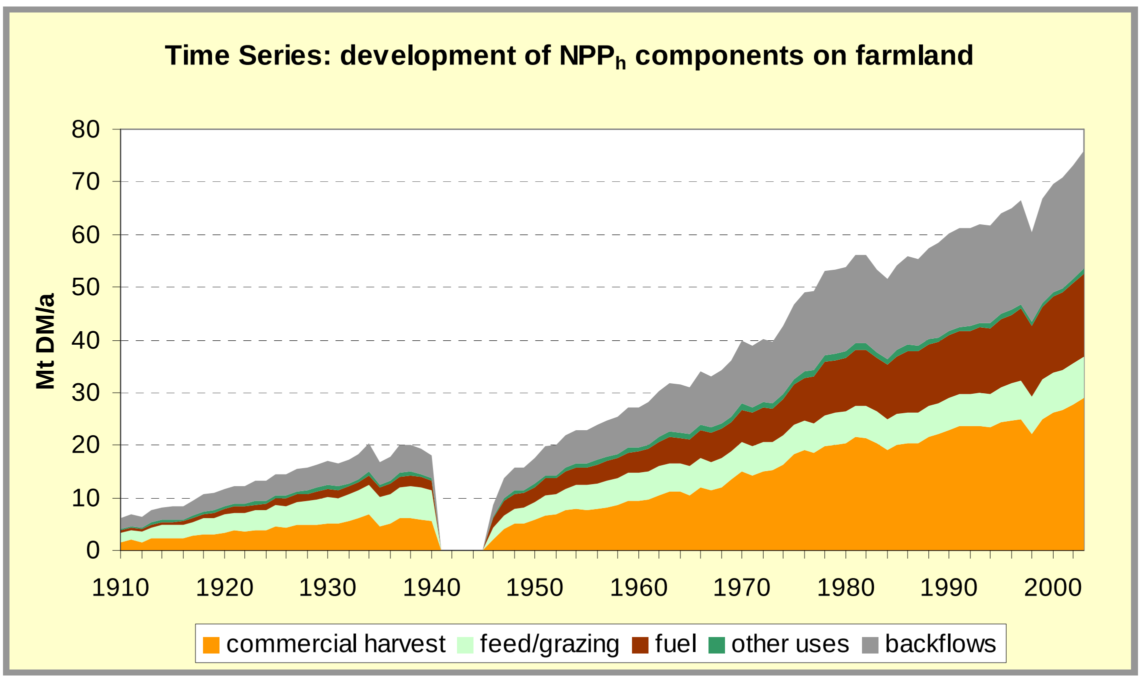

Figure 11 Development of NPP_h on farmland in the Philippines 1910-2003; uses of harvested by-products and non-commercial harvest are distinguished.

Livestock feed

Total livestock feed demand rose more than six fold from under 5 Mt DM per year to over 30 Mt DM per year over the period this study focuses on (Figure 12). In the beginning of my time series, carabaos, the traditional working animal, held the largest share in total feed demand. It has to be noted that livestock populations can be considered in a recovering state following the wars and turmoil at the turn of the century[18]. A similar recovery phase can be observed after World War II. Development in pre-war data seems too linear which could arise from simple estimation methods used by the colonial authorities in those years. Number of carabaos (and their feed demand) stagnated since the 1960s also due to the introduction and spread of agricultural machinery. Feed demand of pigs, poultry and cattle increased considerably following the demand for meat products. The strong increase from the mid 1980s onwards can be attributed to the rise of commercial large scale poultry and pig farming. Recently, the availability of imported feed also increased (e.g. corn and soy cake)[19].

The largest share of livestock feed can be considered to be grazed biomass (Figure 13). Feed from crop by-products seemed to play a comparably minor role and declined in importance. The share of market feed increased a great deal over the past decades, for the reasons just mentioned.

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[18] An uprising against the Spanish reign started in 1896 in the Philippines, who were also a stage for the Spanish-US war from 1898 on, which was followed by Filipino-US War; the latter ended 1902 officially but in reality dragged on well into the first decade of the 20th century; e.g. carabao population was decimated to 10-15% of its 1896 level by 1902 (see e.g. Corpuz 1997).

[19] The Philippines are a founding member of the WTO (1995) and since then, removed quantitative restriction on corn and soy bean imports. This has lead to a significant increase in imports in these commodities from 1995 onwards (Cardeans et al. 2005).

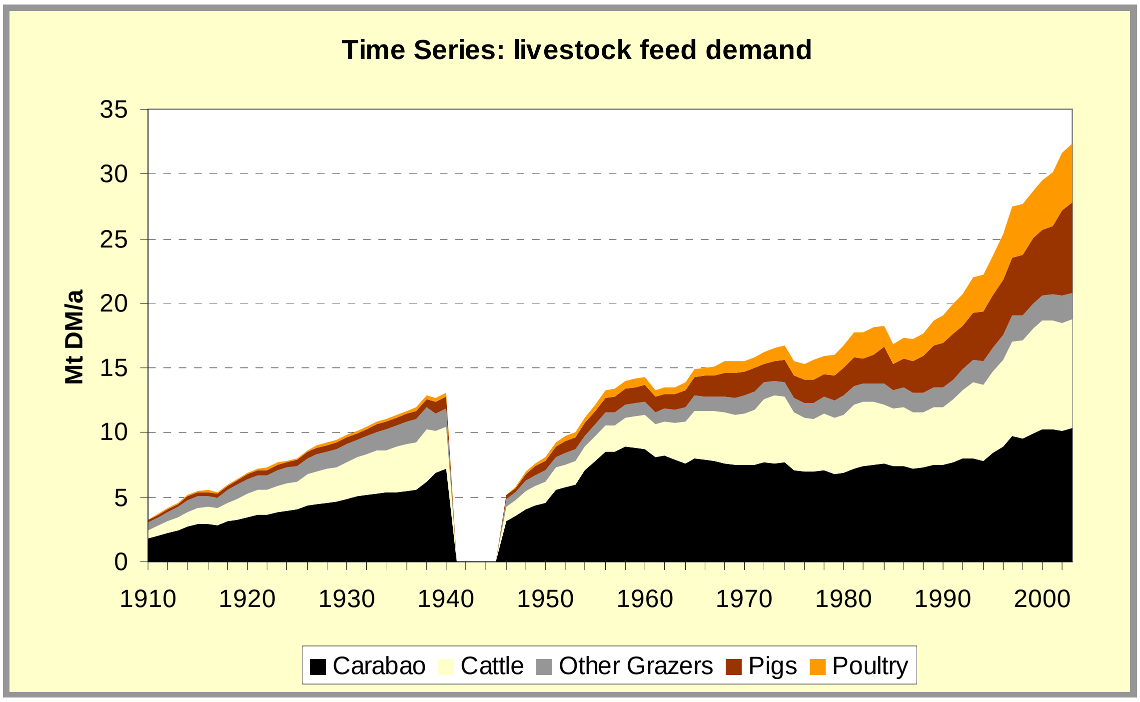

Figure 12 Development of absolute livestock feed demand in the Philippines 1910-2003 by species group;

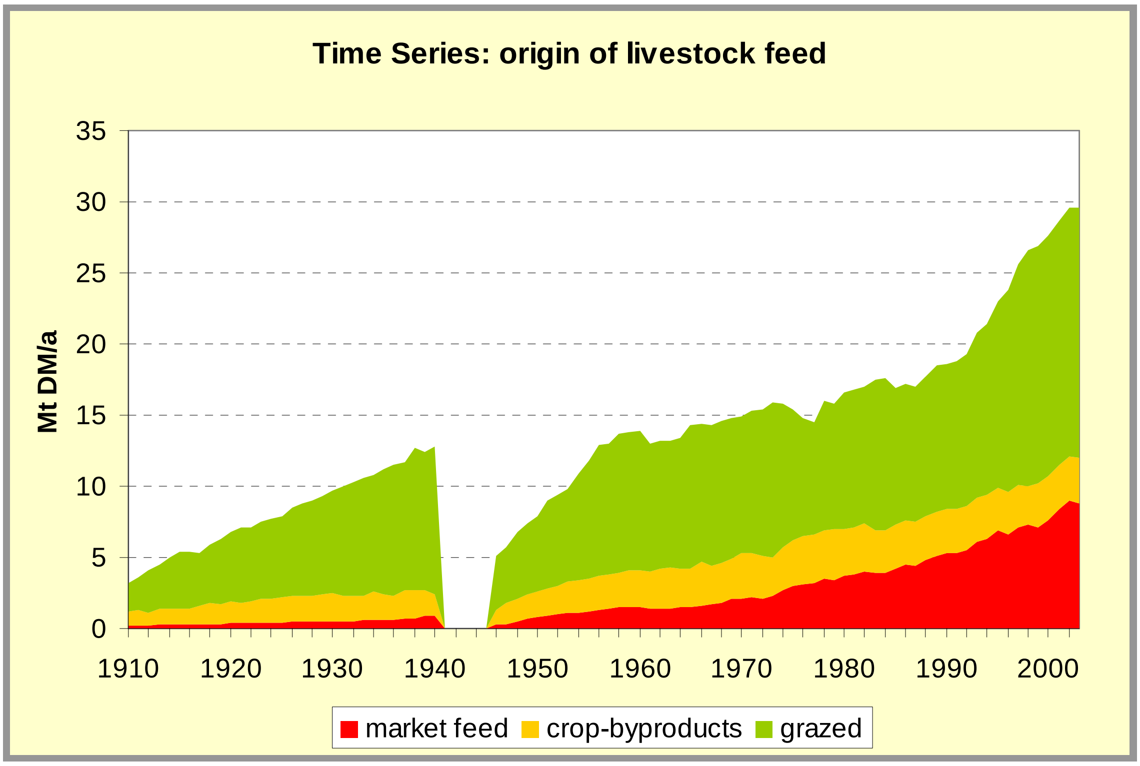

Figure 13 Development of origins of livestock feed in the Philippines 1910-2003

Taking a closer look at the origin of the grazed biomass with respect to land use, it can be noted that grassland holds the largest share in recent years. The relative importance of farmland declined as idle farmland that can be grazed became rarer (Figure 14).

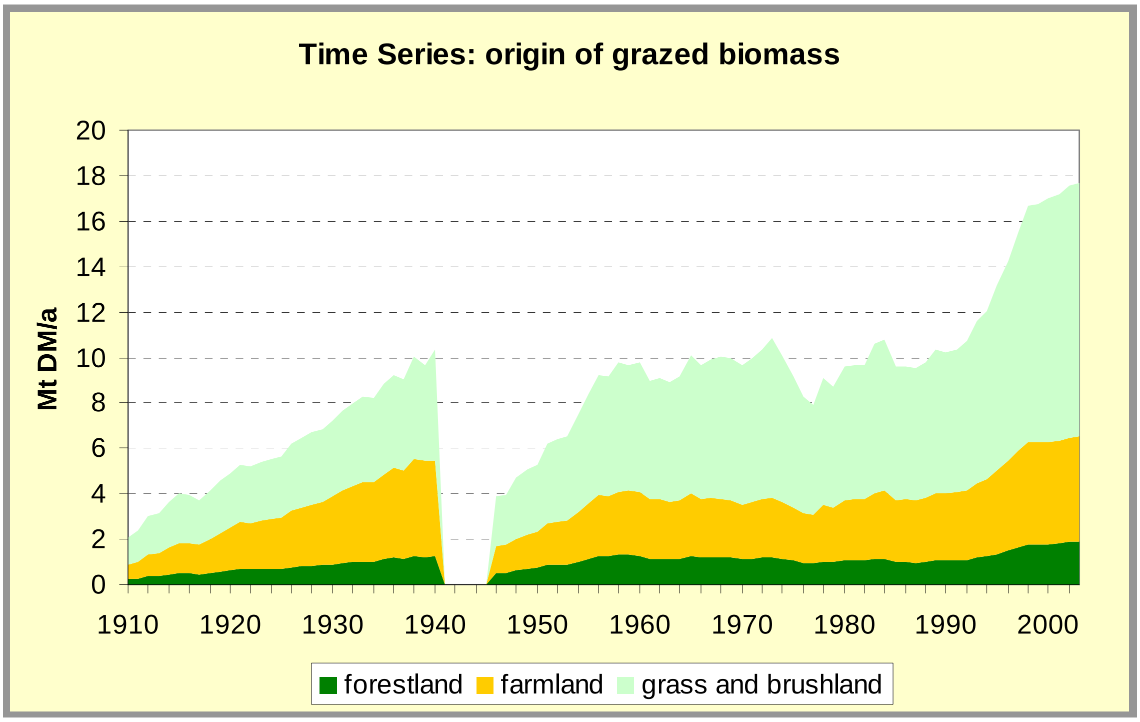

Figure 14 Development of origin of grazed biomass by land use in the Philippines 1910-2003

Wood harvest

The development of wood harvest over the last century in the Philippines gives an interesting, yet also alarming, picture. For industrial wood, a distinct peak at about 20 Mt DM per year in the 1970s can be observed (Figure 15). Much of this harvest was directly exported as unprocessed logs (Bautista 1990). The high share of residues in total harvest is owing to the low recovery rate in tropical wood industries. Only a very small share of this large resource of residues was used throughout the observed period. In recent years the nation became a net importer of wood products and there is a ban on log exports with the aim of fostering the national processing industry. Cheap wood, available on the global market, however, is undermining reforestation efforts (Shimamoto et al. 2004 and Tumaneng-Diete et al. 2005).

Harvest of wood, primarily for fuel purposes (Figure 16) shows a peak as early as 1960 according to my data. It has to be noted that data for wood fuel before 1961 are simple per capita assumptions; therefore, this data should be interpreted with caution. However, the fact that a peak occurred during the last century can be assumed quite certain considering the development of population and forest area. The amount of wood fuel harvested is considerably higher than industrial wood harvest at the beginning and the end of my time series. For the peek years, however, this picture is slightly reversed.

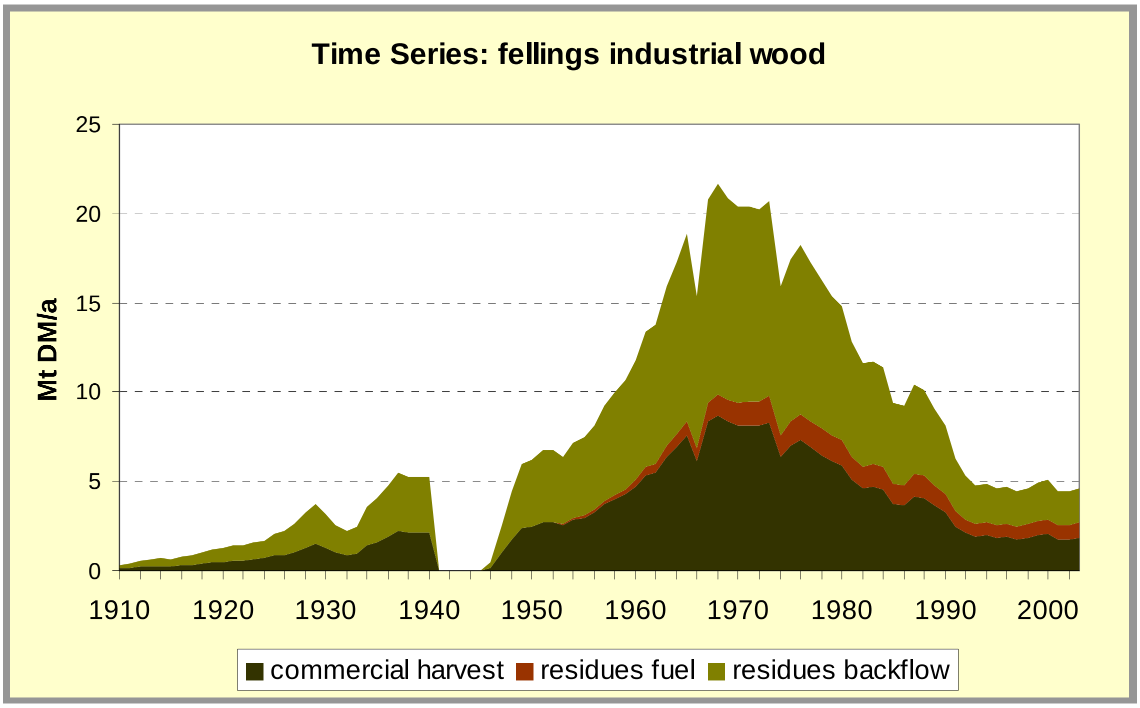

Figure 15 Development of total industrial wood harvest in the Philippines 1910-2003; residues are included

Figure 17 compares the official FAO data used in my study to data calculated from Bautista (1990) for the years 1955-1987. Bautista gives an idea of the extent of illegal logging activities by using Japanese import data and comparing these with Philippine export data. Looking at the data, it becomes obvious that underestimation in official figures could be dramatic. The values according to Bautista are over a third higher than the official ones, peaking at over 30 Mt DM per year[20].

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[20] In both cases the total peak occurs around 1973, the year that President Ferdinand Marcos proclaimed martial law in the Philippines. He allowed his allies to exploit marketable forest stands in a “hit and run” manner (Kummer 1992a). Wood was often sold abroad without proper reporting and no tax payments.

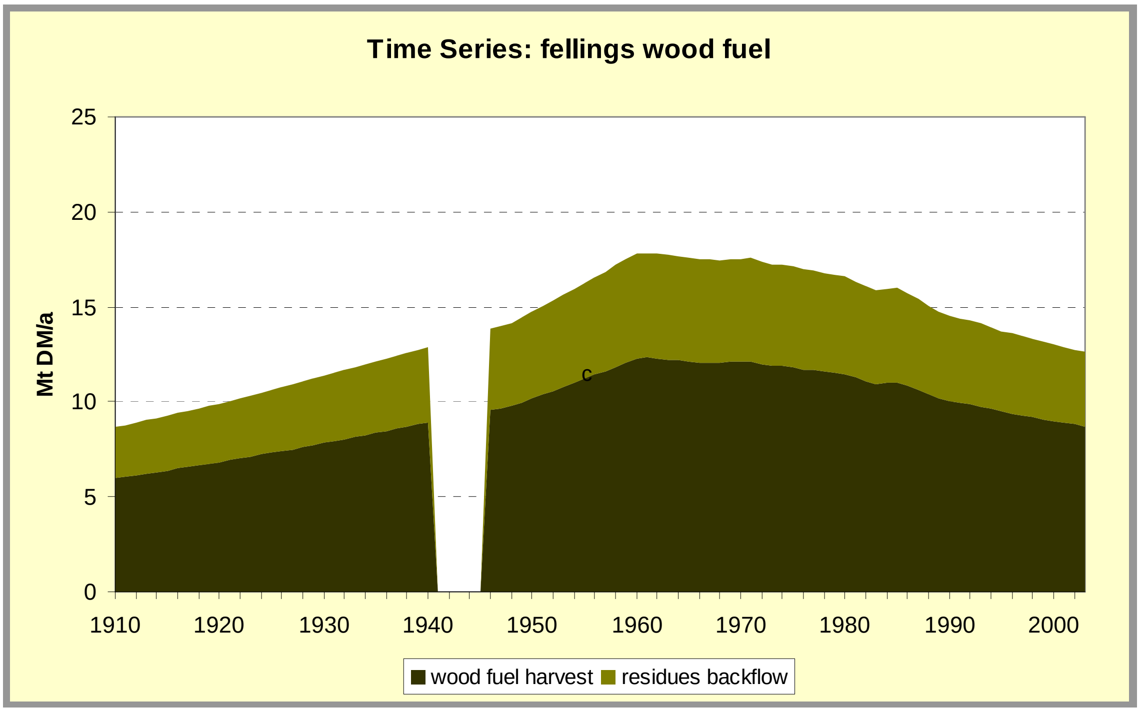

Figure 16 Development of total wood fuel harvest in Philippines 1910-2003; residues are included

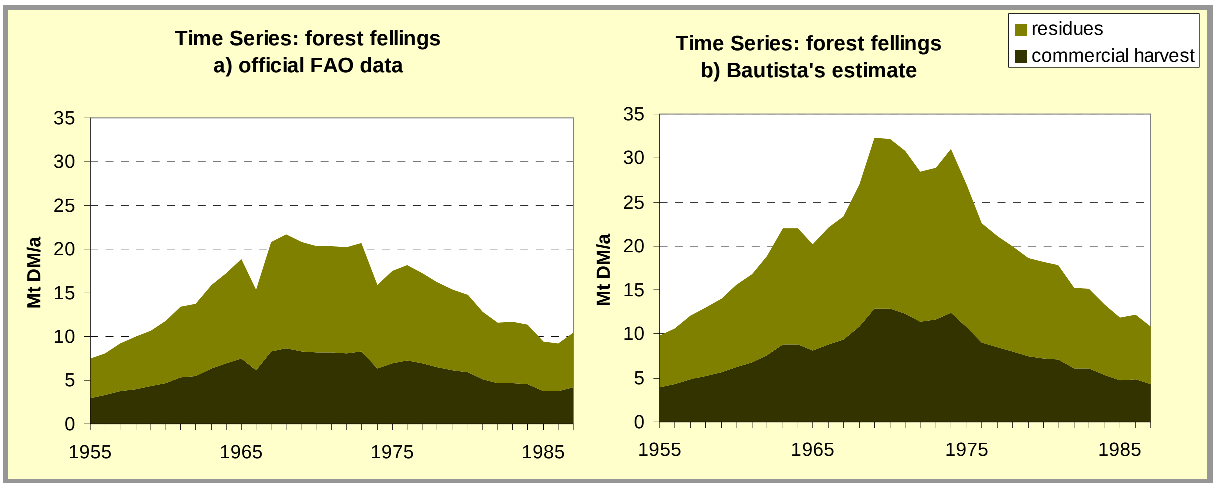

Figure 17 Development of forest fellings related to industrial wood production 1955-1987 based on (a) official (FAO) data and (b) own calculations trying to consider illegal log exports based on Bautista (1990)

Human-induced fires

I present an estimate of biomass burned in human-induced fires with and without the slash and burn estimate (Figure 18), also showing on what land use the biomass is burned. When not considering slash and burn, the regular burning of grasslands accounts for almost all burned biomass; the value is almost constant and rises from somewhat below 10 Mt DM per year to slightly above this value as grasslands expand. The estimate that tries to incorporate biomass burned through slash and burn practices, however, shows a very different picture. Following my assumptions mentioned in the methodology section, the yearly burned biomass declines from almost 50 Mt DM per year to about 30 Mt DM per year (Figure 18b). This decline is due to the assumed decline in the extent of swidden agriculture on the one hand, and due to decline of forests on the other hand. As forest area declines and brushlands increase, I assume the latter are utilized and burned by swidden farmers more often. Per hectare biomass of these lands is considerably lower than that of forests, as increased pressure on the land and shortened fallow periods often do not allow for a proper re-growth into forest.

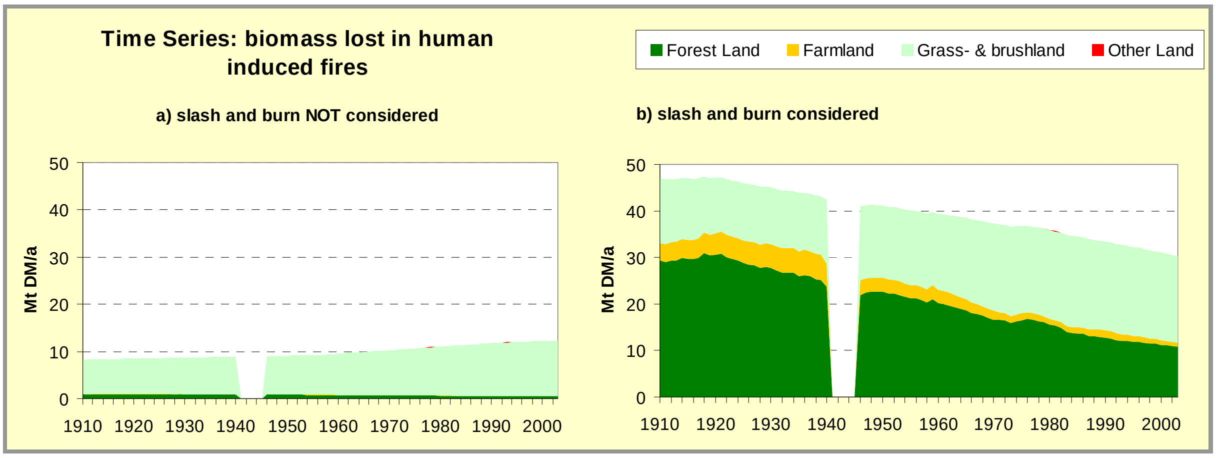

Figure 18 Development of biomass burned through human-induced fires (a) without and (b) with my estimate for slash and burn agriculture in the Philippines 1910-2003; biomass burned is presented according to the land use of its origin

Table 24 intends to give an idea of the significance of including (or not including) the amount of biomass burned in slash and burn practices in my HANPP estimate. If included, especially in the early years of my time series, its share in $ANPP_h$ would be striking, raising its value almost threefold and contributing to $ANPP_h$ substantially throughout the studied period. Also, the obtained development of the overall HANPP value looks very different if the estimate for swidden farming is included, and could very well lead to different interpretations when viewing only the development of HANPP values.

Synthesis of the different $ANPP_h$ types

Total biomass harvest rose from about 25 Mt DM per year in 1910 to almost 120 Mt DM/a in 2003 as can be seen in Figure 19 which also distinguishes the share of its different components. Figure 20 shows the development of the single components more clearly. Backflows are by far the largest component in the beginning; they stagnate from the 1970s onward. Towards the end of the presented time series, commercial crop harvest almost reaches their level. At the lower end, we find industrial wood harvest – however, this harvest is responsible for a relevant share of backflows and might be an underestimation due to lack of data on illegal logging (see above). The decline of industrial wood harvest after the 1970s is also the main reason for the mentioned levelling off of total backflows. If biomass burned through slash and burn practises were included, it would be dominant compared to the other $ANPP_h$ components until about 1960 and commercial crop harvest (the leading component used by society) well into the 1970s.

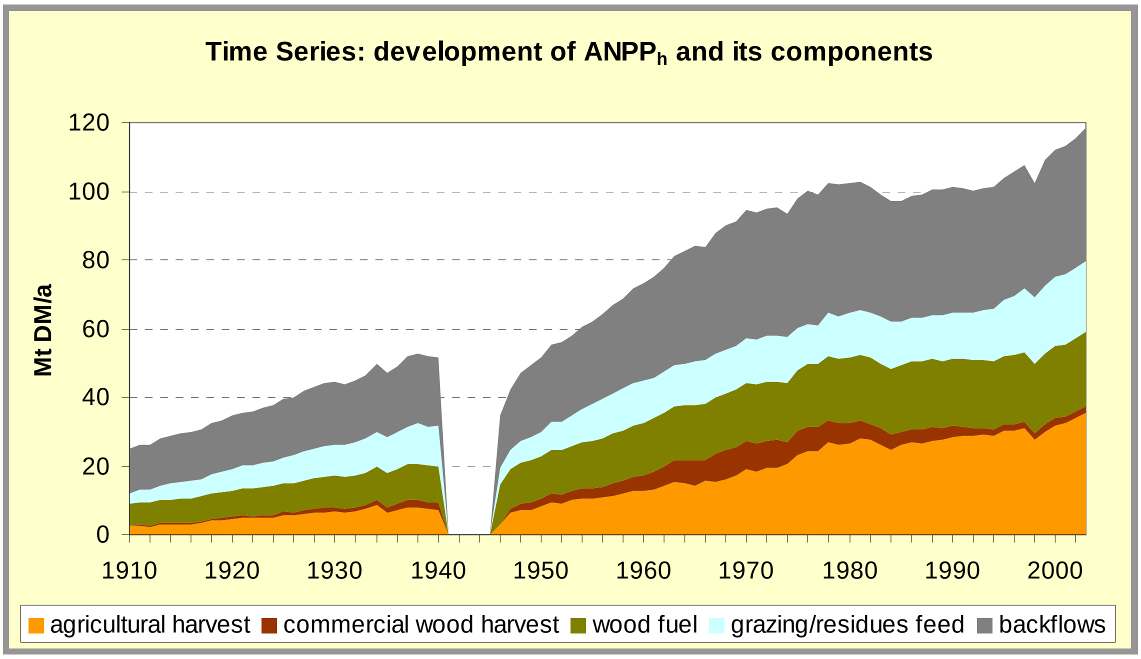

Figure 19 Development of total $ANPP_h$ in the Philippines 1910-2003 and relative share of its components

Figure 21 takes a closer look at the relation of harvested biomass passing through human society and direct backflow to nature. It is obvious that over time, an increase in efficiency occurs. I use the ratio of $ANPP_h$ with societal use to total $ANPP_h$ as a measure of this efficiency. Without including the slash and burn estimate, it increases from about 45% to over 60%. The increase is much more drastic when my slash and burn estimate is incorporated into the calculation (from under 20% to about 55%). This is what one would expect since biomass burned to clear swidden sites constitutes a direct backflow to nature in the HANPP concept.

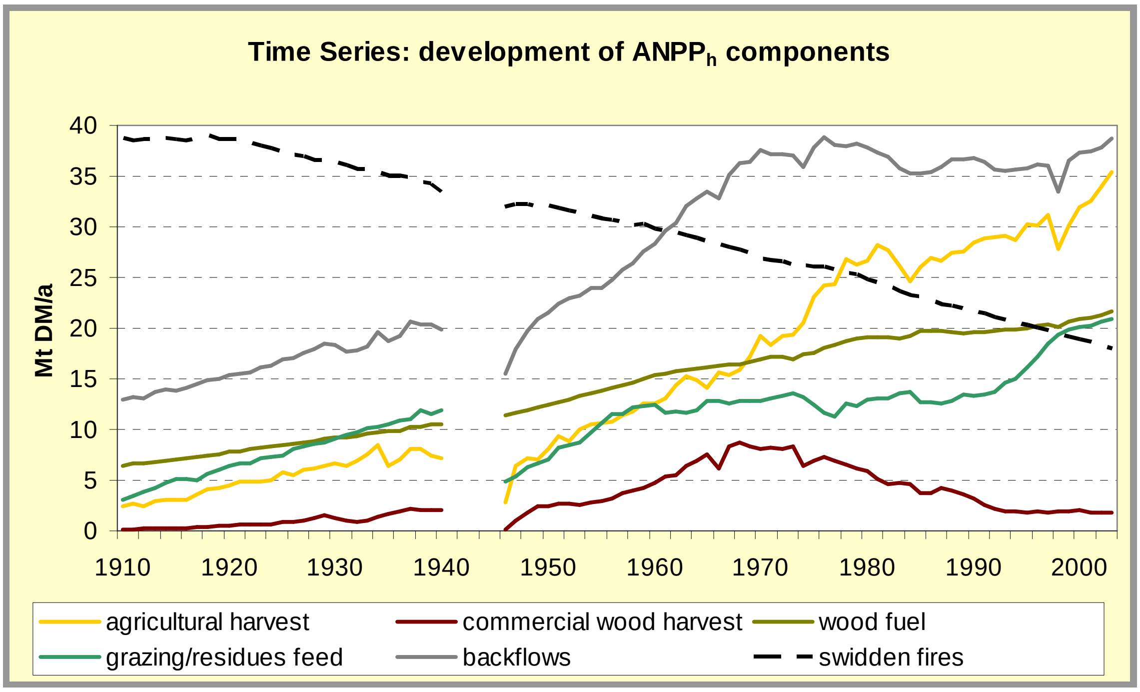

Figure 20 Development of ANPPh components in the Philippines 1910-2003; biomass burned through slash and burn practises is shown (dashed line) but not considered in my totals unless noted otherwise

Per hectare values for harvested biomass are highest for farmland throughout the period (Figure 22). A striking increase from about 2 t DM per hectare and year to almost 8 t DM/ha/a in recent years can be observed. On forest land, the peak related to the describe developments in wood harvest is obvious. It prevails even when considering the declining forest area by using per unit values. Using the official data, the peak can be found at about 4 t DM per hectare and year around 1970. This could have been considerably higher if illegal logging and slash and burn practices are considered (see above). On grass- and brushland, the value is dominated mainly by the burning of grasslands and to a lesser extent by grazing. It is about 2 t DM per hectare and year throughout the whole period.

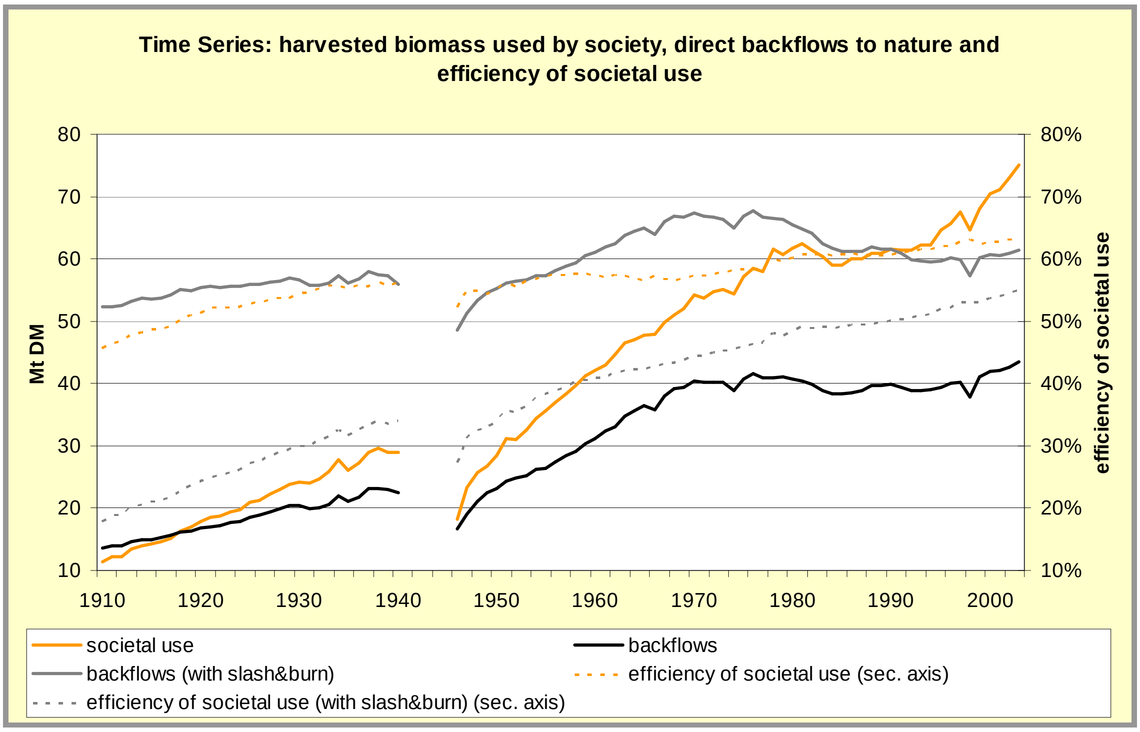

Figure 21 Development of ANPP$_h$ used by society and direct backflows to nature in the Philippines 1910-2003; efficiency of societal use as share in total ANPP$_h$ is shown on the secondary axis (dashed lines); the development is shown with and without the incorporation of the slash and burn estimate.

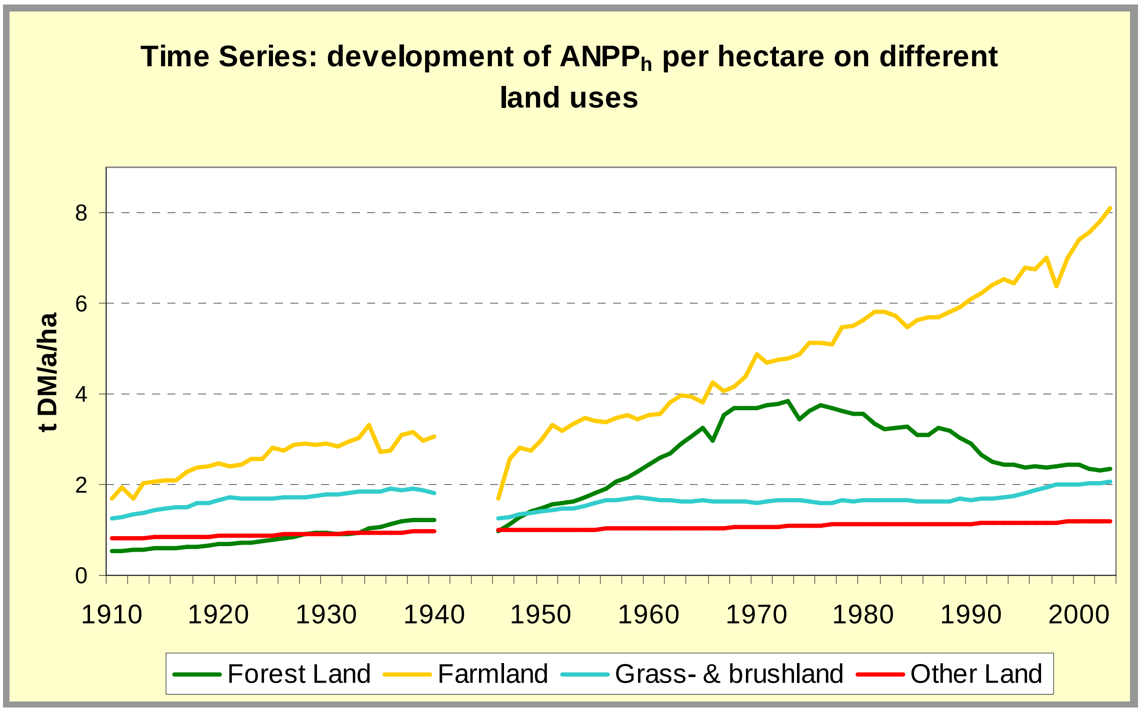

Figure 22 Development of ANPP$_h$ per hectare on different land uses in the Philippines 1910-2003

HANPP

The final result of my calculations – the development of aboveground HANPP in the Philippines from 1910 to 2003 – can be seen in Figure 23. Expressed in per unit area values total aboveground HANPP more than doubled from below 3 t DM/ha/a at the start of my time series to well above 6 t DM/ha/a, recently. In absolute values, this corresponds to an increase from below 100 t DM per year in the beginning of the 20th century to almost 200 t DM per year in recent years. That translates into a rise from below 25% of $ANPP_0$ in 1910 to about 57% of $ANPP_0$ in 2003. When considering my slash and burn estimate, the increase remains significant from 4 t DM/ha/a in 1910 to 7.2 t DM/ha/a in 2003, corresponding to 34% and 62%, respectively (Figure 23b). It should be noted that per unit area values are average figures. HANPP was most likely quite unevenly distributed throughout the studied period; however, due to the fact that this research relates to the national level, this distribution was not assessed. According to the presented assessment, humans have appropriated significantly more than 50% of the total ANPP of the Philippines over the past decades. With less than half of the potential energy base left for other organisms, one would suspect that strains on biodiversity are severe. Indeed the nation is facing a very high rate of biodiversity loss (WWF 1998). A relationship between levels of HANPP and biodiversity loss has been suggested (Wright 1990 and Haberl et al. 2007b) and it would be interesting to establish a link in the Philippine context; however, this is beyond the scope of this study.

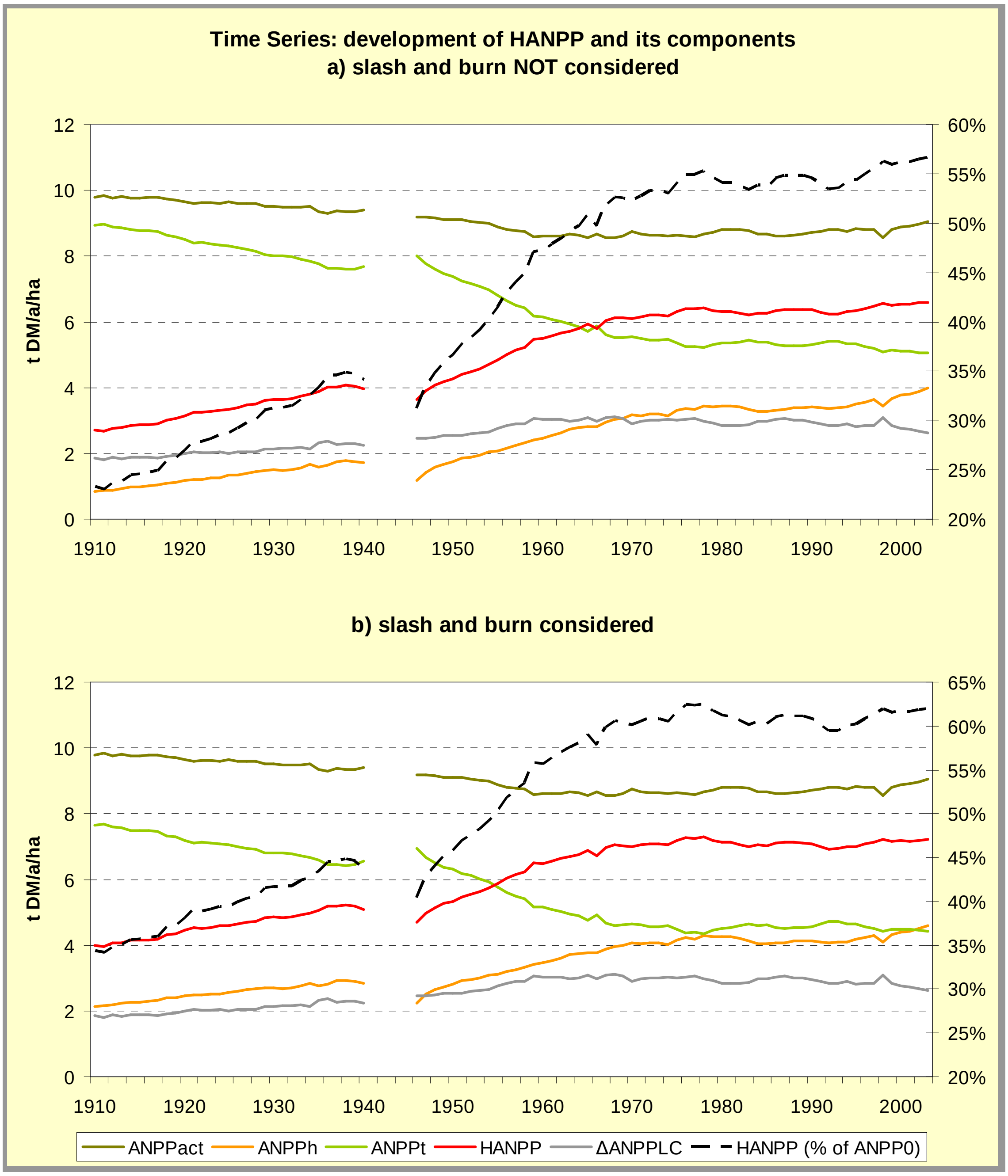

Figure 23 Development of HANPP and its components in the Philippines 1910-2003 (a) without and (b) with the consideration of biomass burned through slash and burn practices; expressed per unit area in t DM/ha/a; development of HANPP in percent of $ANPP_0$ is shown on the secondary axis (dashed black line)

I now take a closer look at the components of HANPP to reveal their share in the total development. Table 24a shows the contribution of the two factors that constitute HANPP for selected years: ANPP foregone due to human-induced changes in productivity ($\Delta ANPP_{LC}$) and biomass harvested by humans ($ANPP_h$). While in the beginning, $\Delta ANPP_{LC}$ is considerably lower than $ANPP_h$ by 1970, the picture is already slightly reversed and in recent years, $ANPP_h$ contributes more to total HANPP than does $\Delta ANPP_{LC}$ [21]. Table 24b shows the same development as Table 24a but considering the biomass burned through slash and burn practices as described above. The difference in $ANPP_h$ compared to the estimate without this inclusion is striking, especially at the beginning of my time series, when it is more than 2.5 times higher if slash and burn is included. Over time, this factor becomes smaller as other $ANPP_h$ components increase, and most likely, slash and burn is gradually pushed back as more semi-sedentary or sedentary forms of agriculture become dominant[22].

Table 24 Development of $\Delta ANPP_{LC}$ and $ANPP_h$ and HANPP in percent of $ANPP_0$ in the Philippines for selected years

a) w/out slash and burn	**1910**	**1925**	**1939**	**1955**	**1970**	**1985**	**2000**
$\Delta ANPP_{LC}$	16%	17%	20%	24%	25%	26%	24%
$ANPP_h$	7%	11%	15%	18%	27%	28%	32%
HANPP	23%	29%	35%	42%	53%	54%	56%
b) w/ slash and burn	**1910**	**1925**	**1939**	**1955**	**1970**	**1985**	**2000**
$\Delta ANPP_{LC}$	16%	17%	20%	24%	25%	26%	24%
$ANPP_h$	18%	22%	25%	27%	35%	35%	38%
HANPP	34%	41%	45%	51%	60%	60%	62%

(a) without (b) with considering biomass burned in slash and burn practices

Figure 24 shows a compilation of the development of different HANPP components in respect to the four main land uses over time. Table 25 gives a detailed breakdown of HANPP% and its two constituting components, showing the contributions of the respective land uses for selected years over the time series. Some interesting developments become obvious here. Throughout time, farmland and grass- and brushland are the leading contributors to total HANPP. In the year 2000, they are responsible for 46.4% of the total of 56.3% HANPP. Between the two, their share seems more or less balanced over time. Relating to forest land, the

[21] It is interesting to observe that between 1970 and 1985 seemingly only a very slight increase of $ANPP_h$ occurred. This period corresponds more or less to the time when ex-president and Dictator Ferdinand Marcos declared martial law in 1973 and the end of his reign in 1986. However, a closer look a the data reveals that $ANPP_h$ rose to about 30% at the end of the 1970s and declined again in the beginning of the 1980s, probably also due to the economic crises during the last years of Marcos reign and in the years after his fall.

[22] If land is fallowed for shorter periods and cultivation periods get longer, the system can no longer be called shifting cultivation, and the relevance of biomass burning becomes small in relation to HANPP because of limited time for biomass re-growth and land degradation.

peak in the 1970s is also evident in total HANPP. On other land, the increase in fishpond area and settlement and infrastructure area contribute to the increase in HANPP%.

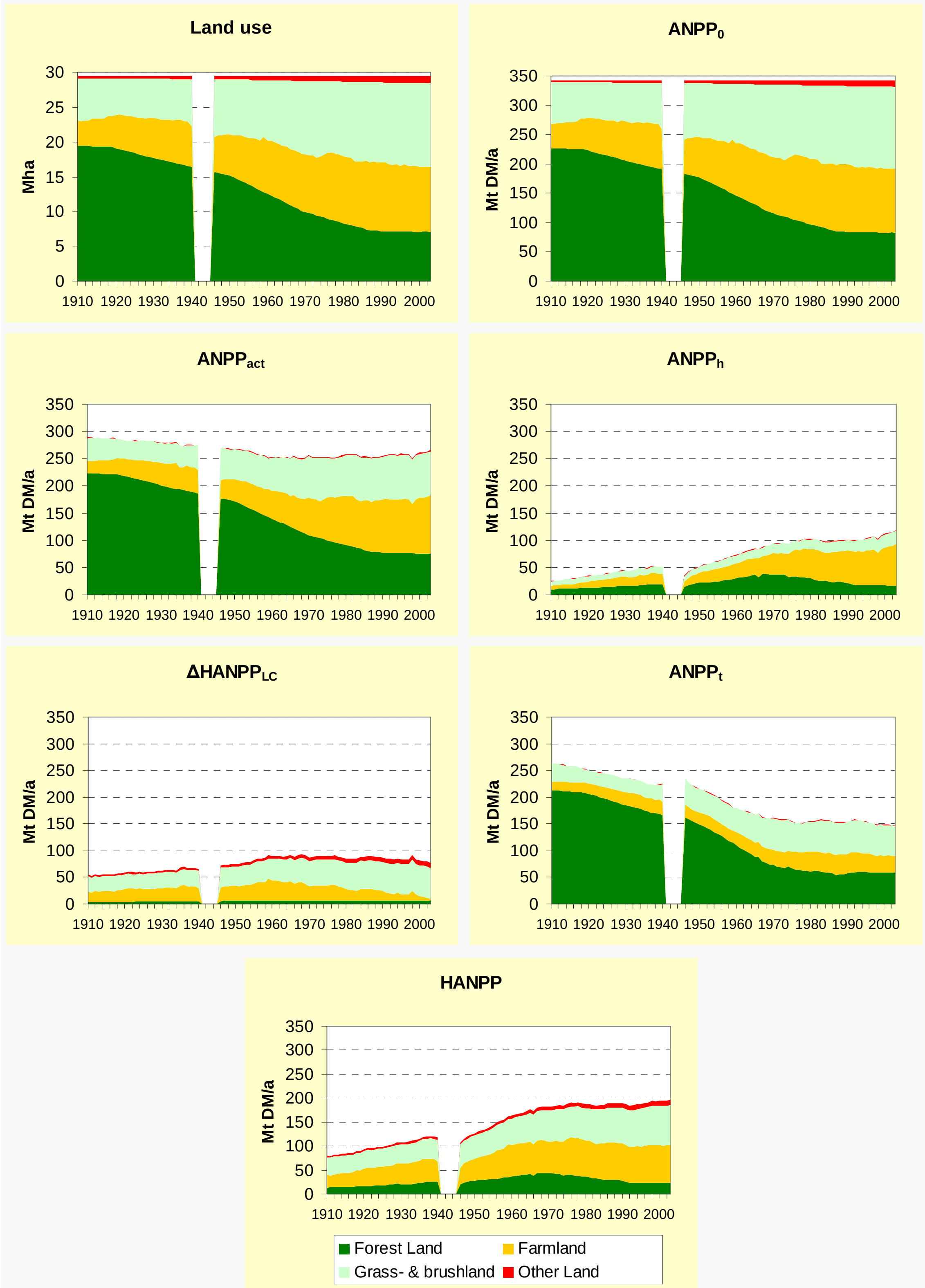

Figure 24 Development of the four main land uses and of HANPP and components in the Philippines 1910-2003 on these land use classes

Table 25 HANPP% per land use for selected years and the contributions of $\Delta ANPP_{LC}$ and $ANPP_h$

Total HANPP%	**1910**	**1925**	**1939**	**1955**	**1970**	**1985**	**2000**
Forest Land	3.9%	5.2%	7.1%	8.8%	12.3%	8.5%	7.0%
Farmland	7.6%	10.8%	13.6%	16.0%	19.2%	21.8%	22.4%
Grass- & brushland	11.3%	11.9%	13.2%	15.7%	19.1%	21.4%	24.3%
Other Land	0.5%	0.6%	0.8%	1.1%	1.6%	2.0%	2.5%
Total HANPP	23.2%	28.6%	34.7%	41.5%	52.3%	53.7%	56.2%
Contribution of $\Delta ANPP_{LC}$							
Forest Land	1.0%	1.2%	1.5%	1.7%	1.8%	1.8%	2.0%
Farmland	5.8%	6.7%	8.1%	9.4%	7.7%	6.2%	2.4%
Grass- & brushland	8.8%	8.8%	9.5%	11.6%	14.1%	15.9%	17.2%
Other Land	0.4%	0.5%	0.7%	0.9%	1.4%	1.8%	2.1%
Contribution of $ANPP_h$							
Forest Land	2.9%	4.0%	5.7%	7.1%	10.6%	6.7%	5.0%
Farmland	1.7%	4.2%	5.5%	6.6%	11.5%	15.6%	20.0%
Grass- & brushland	2.5%	3.1%	3.7%	4.1%	5.1%	5.5%	7.1%
Other Land	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.3%

Looking at $\Delta ANPP_{LC}$, grass- and brushland make up the predominant share over the entire period under investigation. Over the course of time, this seems to become more pronounces as productivity of farmland increases through agricultural intensification[23]. In fact, $\Delta ANPP_{LC}$ increases on all land uses over time with the exception of farmland. Over the course of time biomass harvest on farmland increases continuously, contributing substantially to total $ANPP_h$. With the exception of forest land, biomass harvest also increases on the other land uses steadily over time, albeit much slower than on farmland.

A stabilization of HANPP can be observed from the late 1960s onwards, while $ANPP_h$ continues to rise constantly, primarily owing to the occurring agricultural intensification. Before the start of this intensification, increases in $ANPP_h$ were achieved mainly by putting more land to permanent cultivation. Agriculture was practiced without major chemical inputs and yields stayed low. The aerial expansion of agriculture translates to HANPP increases through high forgone ANPP and the increases in $ANPP_h$. Through intensification, HANPP can be stabilized via increasing per unit area yields, while $ANPP_h$ continues to rise. A qualitative shift in HANPP from forgone ANPP to harvestable biomass occurs. This process has been described in detail by Krausmann (2001) in his work on HANPP of Austria. A decline in

[23] However, in many cases, it can be assumed that some form of agriculture has been practised on much of the existing grass- and brushland at certain points in time, which holds some kind of responsibility for its degradation (i.e. lower productivity).

HANPP, however, can be expected only if farmland is converted to forest land where per unit area harvest is typically lower. Considering the imminent population pressure in the Philippines such a development seems unlikely. A possible way to decrease HANPP and increase the actual productivity could be to rehabilitate degraded grass and brushlands, which has proven to be a challenging task (Chokkalingam et al. 2006).

The ratio of harvested biomass to foregone productivity rises during the studied period from slightly over 40% to over 140% (Figure 25). The increase is rather continuous, with a drop after World War II.

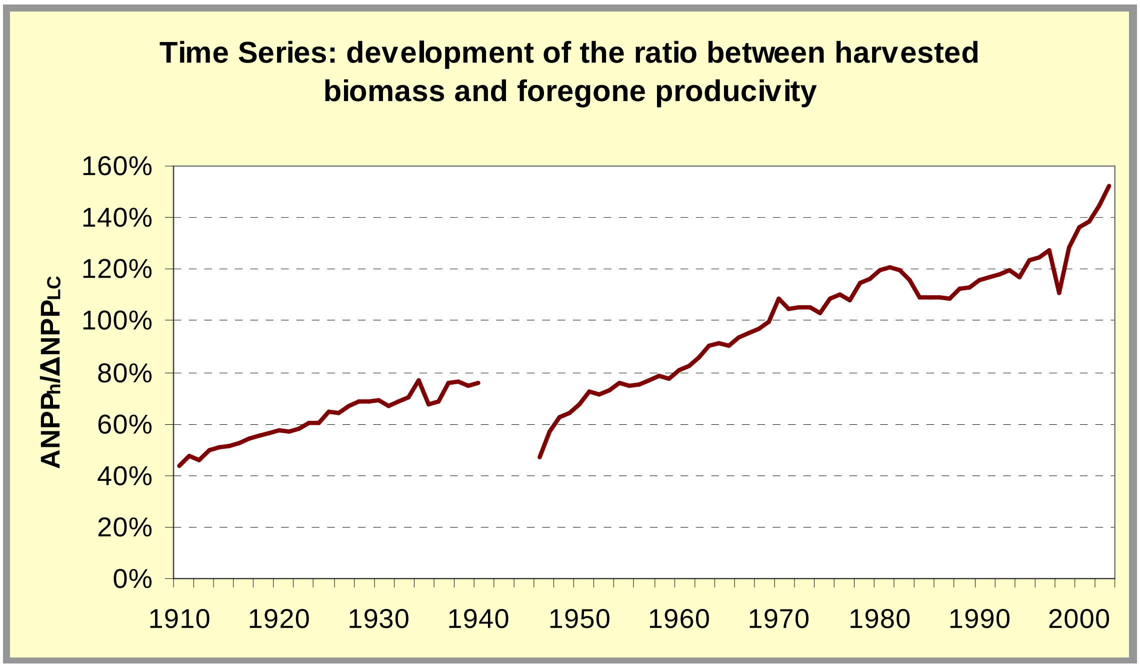

Figure 25 Development of the ratio of $ANPP_h$ and $\Delta ANPP_{LC}$ in the Philippines 1910-2003

The share that biomass harvest has in total HANPP can be considered a measure of how efficient the process of societal appropriation is, since foregone productivity cannot be used, neither by humans nor by ecosystems. However, since direct backflows to nature are also part of $ANPP_h$, maybe the share that harvested biomass used by society has in total HANPP would be a better measure of actual efficiency. Table 26 shows these measures for efficiency for selected years, again without and with the inclusion for my estimate for slash and burn.

Table 26 Efficiency of $ANPP_h$ and biomass harvest with societal use in respect to total HANPP in the Philippines for selected years

w/out slash and burn estimate	1910	1925	1939	1955	1970	1985	2000
HANPP%	23%	29%	35%	42%	53%	54%	56%
Efficiency $ANPP_h$/HANPP	31%	40%	43%	43%	52%	52%	58%
Efficiency societal use/HANPP	14%	21%	24%	24%	30%	32%	36%
w/ slash and burn estimate							
HANPP%	34%	39%	45%	50%	60%	60%	62%
Efficiency $ANPP_h$/HANPP	53%	56%	56%	53%	58%	57%	61%
Efficiency societal use/HANPP	10%	15%	19%	20%	26%	28%	33%

Without question, a drastic increase in the mentioned efficiencies occurred over last century in the Philippines. Harvested biomass per HANPP almost doubled from 30% to 58% while the biomass, which passes through society in any form, increased even more by a factor of 2.7. When looking at the data including the slash and burn estimate, it is of interest to note that the two efficiency measure show different responses to its inclusion. While $ANPP_h$/HANPP becomes higher, the share of $ANPP_h$ with direct societal use becomes lower. One has to be careful when it comes to interpreting such efficiency measures and drawing conclusions from them.

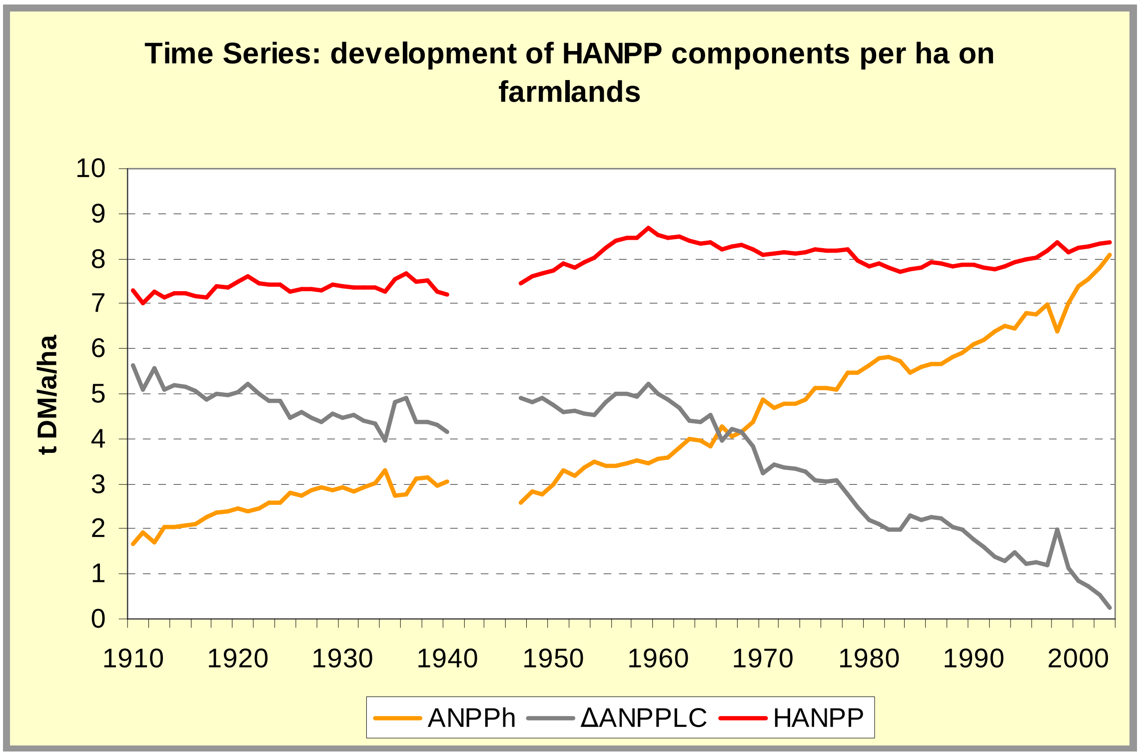

Figure 26 Development of HANPP and components per hectare and year in the Philippines 1910-2003

The single most important reason for the increase of the mentioned efficiencies are changes occurring on farmland. While the increase in farmland area slowed down from the 1970s onwards, per area $ANPP_h$ more than doubled since the start of agricultural intensification in the 1960s. Foregone productivity, on the other hand, is approaching zero, which means that actual productivity is close to potential productivity. Referring to Figure 26, the trend of increased per area harvest seems to be ongoing[24].

Another measure of human dominance in the respective land use systems could be the share that harvested biomass holds in actual productivity of the systems (Figure 27). Here, again, farmlands show a strong increase over time. In recent years ANPP harvested by humans reaches a value of 70% of $ANPP_{act}$. This can be attributed to the decrease in on farm fallows and the increase in external inputs. Grass- and brushland shows values around or below 30%, the largest contribution of this share is held by fire on grasslands which consumes more biomass than grazing at all points in time[25]. For forest land, the peak value in the 1970s reaches about 35% but would most likely be considerably higher if illegal logging could be accounted for properly.

Use of biomass as fuel is a very important component of societal harvest in the Philippines. According to my data, in the beginning of the 20th century most of this fuel came from forest land as there was still more of it available. Over time, a decline of this resource occurred and consequently in recent years, most biofuel stems from other land uses[26] (see Figure 28). Agricultural residues became a widespread biofuel, with coconut residues having an outstanding importance in this category[27].

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[24] The lower value for 1998 can be attributed to the occurrence of El Niño in that year. One could suspect that with a higher level of intensification, sustaining the high level of yields becomes more sensitive to such phenomena; e.g. Kerkvliet (1991).

[25] Grasslands are burned to a large degree by livestock owners to keep their herbaceous/grass cover which is preferred by grazers. However, they are, in general, considered underutilized in respect to grazing (Batcagan 2000).

[26] A study by the World Bank in 1991 claims that only 13.7% of fuelwood consumed by households stems from forest land (World Bank/ESMAP 1991 in Bhattarai 1997), a value that seems somewhat low, as it probably relies on legal definitions of forest land.

[27] Almost one third of total farmland is now planted to coconuts in the Philippines. They provide leaves, husks and shells that are commonly used as fuel.

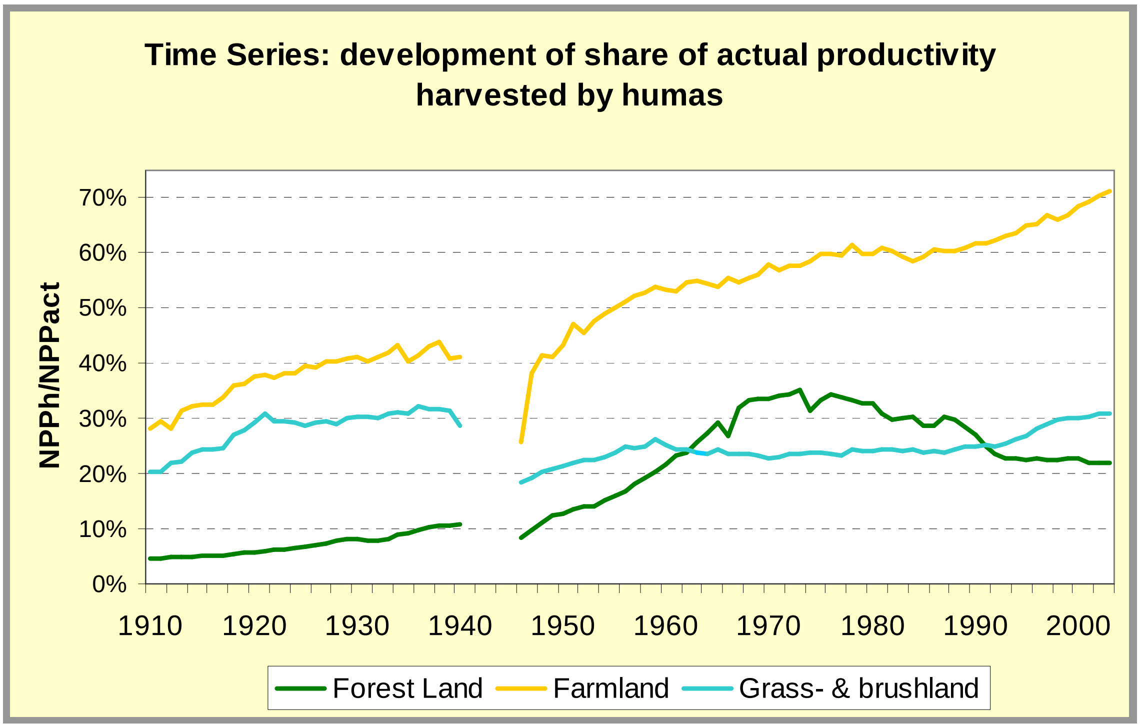

Figure 27 Development of the relation between biomass harvest and ANPPact in the Philippines 1910-2003

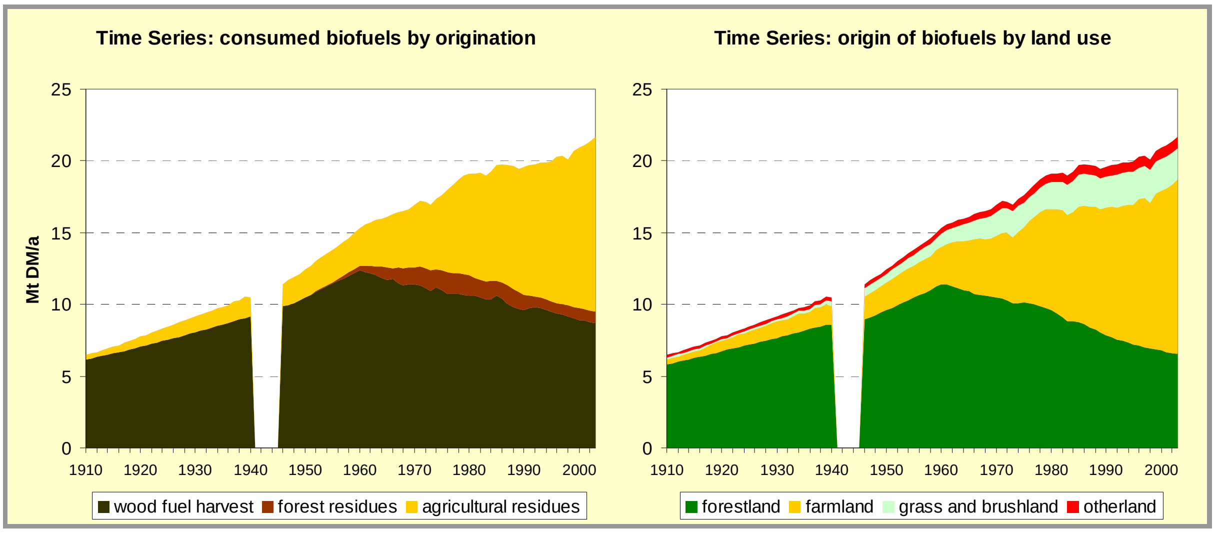

Figure 28 Development of biofuels by origination and land use origin in the Philippines 1910-2003

Discussion

I already provided short discussion inputs related to my calculations in the results section above. In this section I aim to connect the results of my calculations to socio-economic developments in the Philippines to provide a broader picture. After that, a synopsis compiles and discusses major findings and implications of the presented research.

HANPP as related to socio-economic developments

It is interesting to relate the pressures a society imposes upon nature through increasing ANPP appropriation to socio-economic trends, which occur in that the same society over the same period. I try to establish connections of my HANPP time-series results to developments that occurred in the Philippines over the course of the 20th century, namely, population and GDP development, foreign trade of biomass products, and energy and fertilizer consumption.

Population development and selected per capita values

Figure 29 shows the population development in the Philippines from 1910 to 2003. An increase by the factor 10 from about 8 to over 80 million people occurred over the period covered within my research. This development poses the interesting question of how societal metabolism can be maintained in view of such a rapid population growth. Also, if the HANPP% value is already about 25% in the beginning of my time series, a linear population-HANPP relation seems simply impossible for this system. It would yield a HANPP of 250% for the latest population figures, a number that arguably could only be reached on a local level but not for a nation like the Philippines over a long time span.

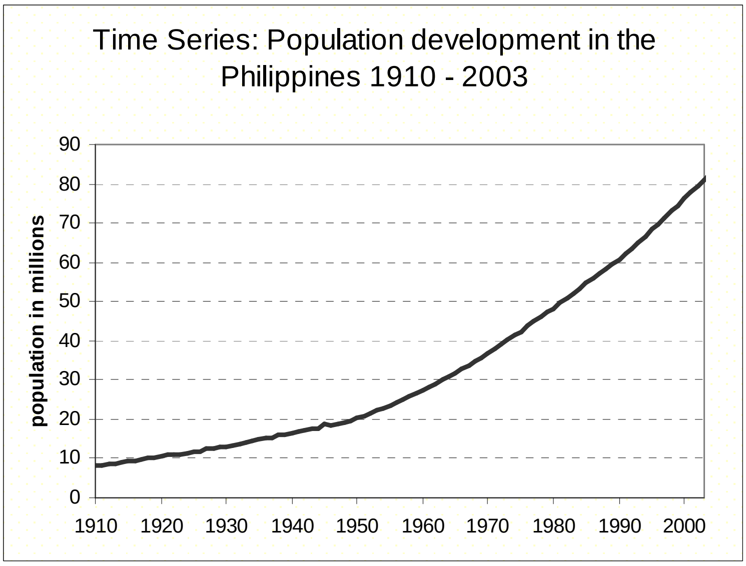

Figure 29 Population development in the Philippines 1910-2003

In Table 27, I take a look at various per capita values for the Philippines for selected years. As expected, there is a decline in all categories, in relation to the development of per capita land availability. This is especially strong for forest land as it decreased in size as population grew. In 2000, it was at 0.09 hectare per capita, not even 4% of the 1910 value of 2.3 hectare per capita. Farmland and secondary vegetation like grass- and brushland increase in absolute area, per capita values, however, decreased significantly. Farmland shows the lowest decrease with the 2000 value of 0.12 hectare per capita still above a quarter of the 1910 value. It is striking that the value for farmland in 1910 of 0.44 hectare per capita is higher than total per capita land availability in the Philippines in 2000. This already gives an indication that an intensification of land use had to occur over time in one way or another.

Per capita HANPP declined from almost 10 t DM per capita and year in 1910 to about 2.5 in recent years (see Table 27 and Figure 30). This decline would be even more dramatic if the biomass burned due to slash and burn practises, according to my estimate, would be included. $\Delta ANPP_{LC}$ shows a much stronger decline than $ANPP_h$ per capita. While the former drops almost by a factor of 7, the latter decreases only by a factor of about 2. Again, this development (increase in efficiency) seems to be a kind of necessity to sustain the metabolism of a growing population, since only harvested biomass can be used by society, while $\Delta ANPP_{LC}$ can be considered "lost" NPP. Figure 30 also shows that of the HANPP components, per capita $ANPP_h$ is declining the slowest, by far. Before World War II, it could even keep track with population development. After the War, its level was already lower but still could be maintained for some time until it eventually started to drop in the 1960s.

Table 27 Various per capita values for the Philippines 1910-2000 for selected years

Unit	Item	1910	1925	1938	1955	1971	1985	2000
[million capita]	population	8.22	11.67	15.98	25.57	37.90	54.67	76.50
[ha/capita]	forest Land	2.30	1.53	1.02	0.58	0.26	0.14	0.09
	farmland	0.44	0.44	0.40	0.28	0.22	0.18	0.12
	grass- & brushland	0.85	0.55	0.43	0.38	0.29	0.21	0.16
	total land	3.63	2.56	1.87	1.27	0.79	0.55	0.39
[kg DM/capita/a]	HANPP	9 967	8 622	7 643	6 162	4 856	3 420	2 554
	$\Delta ANPP_{LC}$	6 927	5 227	4 335	3 524	2 373	1 634	1 082
	$ANPP_h$	3 040	3 385	3 300	2 631	2 476	1 780	1 467
	commercial crop harvest	296	496	503	449	482	476	417
	industrial wood harvest	17	72	132	127	215	69	27
	biofuels	787	726	645	585	454	360	273
	grazing/residues feed	369	638	746	451	344	232	262
	backflows	1 571	1 452	1 275	1 020	981	644	488
	slash and burn estimate	*4 704*	*3 198*	*2 154*	*1 308*	*705*	*421*	*246*
	HANPP% per million capita	2.9%	2.5%	2.2%	1.8%	1.4%	1.0%	0.7%
[1990 USD/capita /a]	GDP	368	523	560	552	739	810	967
	GDP from agriculture	140	205	214	182	206	199	191
[GJ/capita/a]	fossils and electricity	n.d.	2.5	1.9	3.9	10.4	10.8	18.8
	biofuels	n.d.	13.8	12.2	11.1	8.6	6.8	5.2
[kg DM/capita/a]	staple crop production	102	181	157	160	182	215	201
	biomass export	47	80	97	n.d.	243	58	27
	biomass import	21	n.d.	n.d.	n.d.	36	37	94

Note that the values for the slash and burn estimate is not included in the totals of HANPP and $ANPP_h$

When looking at HANPP% per capita, a severe decline is once again obvious. According to my data, in 1910, it was at 2.9% per million capita, while in 2000, it was only 0.7% for the same number of people. This decrease would have been even steeper if my estimate for slash and burn were considered. It might be interesting to compare these figures to other societies in other environments.

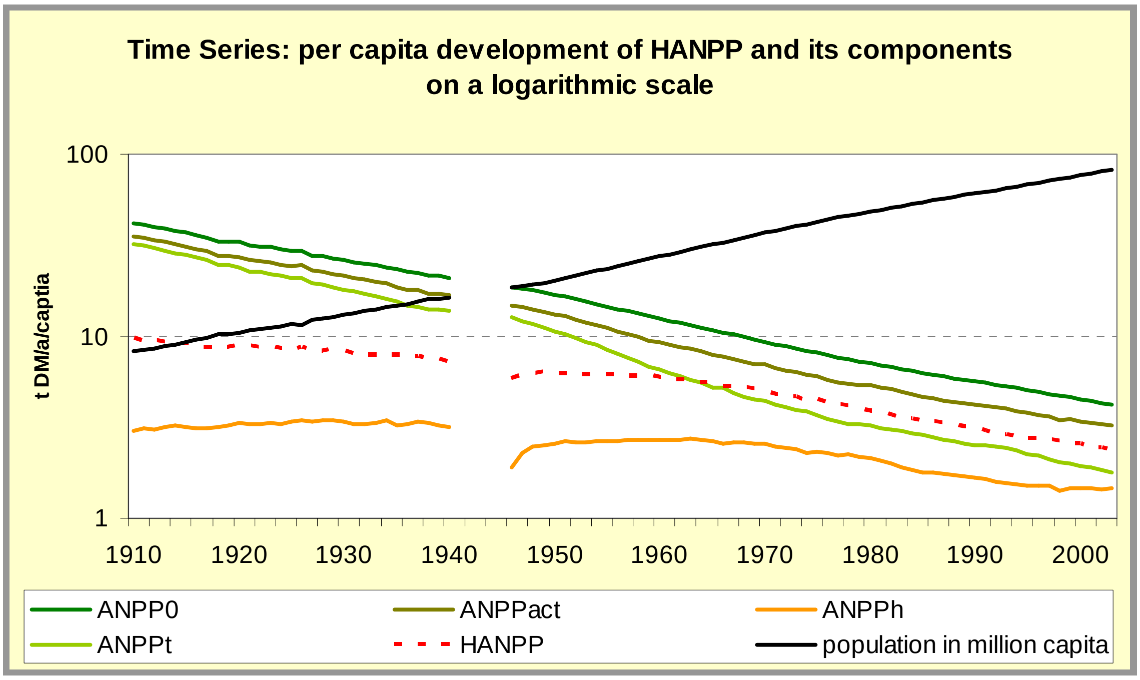

Figure 30 Per capita development of HANPP and components for the Philippines 1910-2003 on a logarithmic scale

A look at the development of the per capita values of different components of harvested biomass (Table 27 and Figure 31) reveals that the only category that could keep track with population growth is commercial crop harvest. Figure 31 tries to visualize these developments by showing them on an index scale with 1960 as base year. It seems that commercial crop harvest "does its best to keep up with population growth". Wars, like the one at the end of the century and World War II constitute major setbacks in this, as did the economic crises in the 1980s and also the vulnerability to natural phenomena such as the El-Niño of 1998. For the other components, they all show an increase over time, however, at a level lower than population development. The exception is the category of industrial wood harvest. During peak years, the lion's share of this category was exported and there seems to be no direct link between this kind of logging operations and population development[28].

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[28] Bautista (1990) reports an export share of over two thirds in the peak years 1971-1975 not considering illegal operations; Kummer (Kummer 1991) cites sources claiming that during the peak years of (also illegal) logging under the Marcos administration, it is believed that the revenue of the operation was essentially for the enrichment of 200 (elite) families, while benefits for the larger share of the population are probably outweighed by costs carried by them.

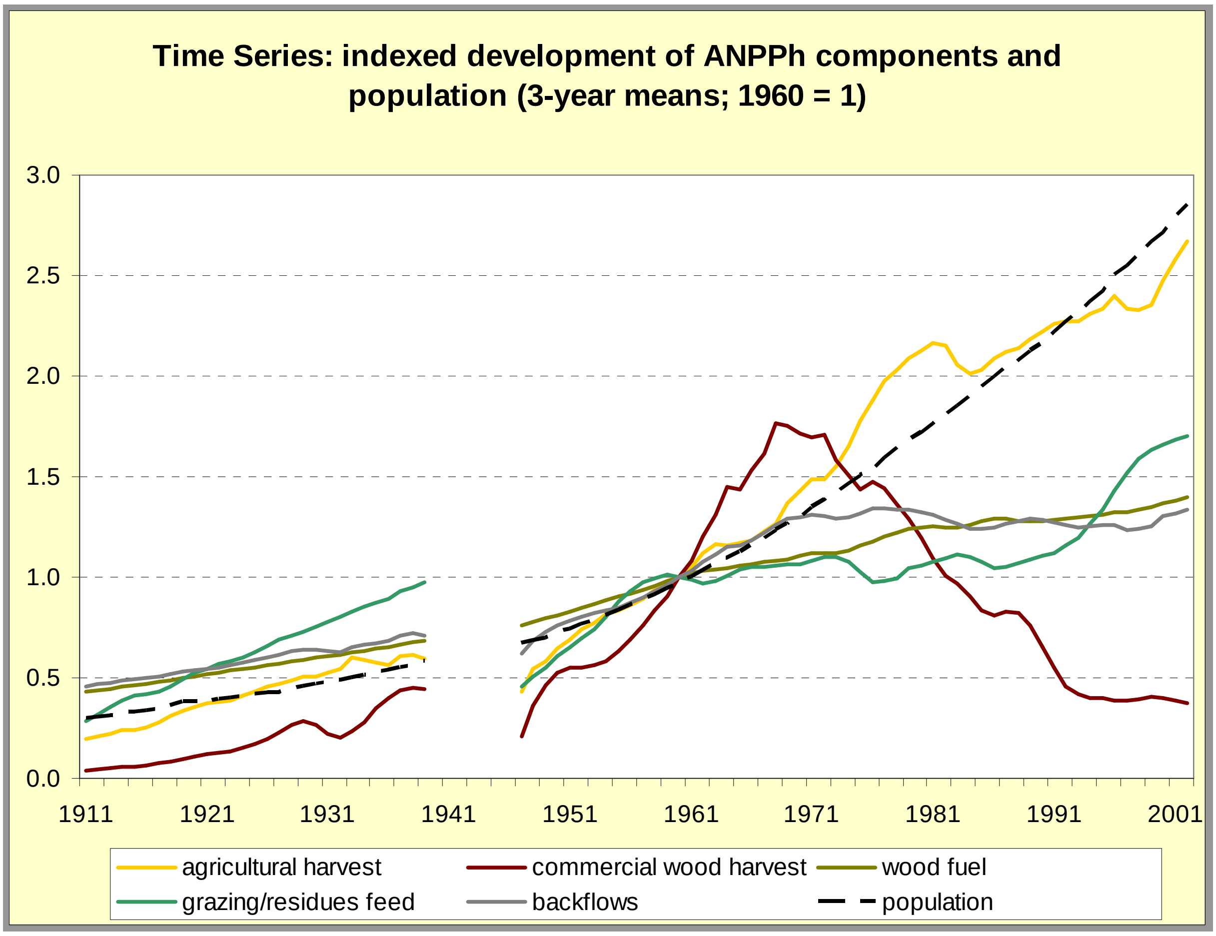

Figure 31 Indexed development of ANPPh components in the Philippines 1910-2003 with 1960 as base year (3-year means)

When discussing area specific per capita values in the Philippine context, the phenomenon of emigration in recent years has to be mentioned. According to the "Migration Information Source"[29] in 2000, about 7.5 million Filipinos stayed abroad (2.9 millions in some kind of temporary working arrangement, 2.5 millions as permanent migrants and 1.8 millions in irregular stays abroad). This is about 10 percent of the total population; when viewing the per capita values for recent years, it should be kept in mind that the number of people actually living in the Philippines is most likely lower than official numbers due to the described emigration patterns. Larkin (1982) describes that over the decade from 1820 to 1920, migration from highly populated regions to lowland frontier regions were common and by the end of this period, the "lowland frontier" was closed. Migration movements became, by then, a common feature of Philippine societies. Kummer (1992b) and Pulhin et al. (2006) describe

[29] http://www.migrationinformation.org/Feature/display.cfm?ID=191, accessed January 20, 2007

that the land frontier in the uplands was closed in the 1970s and 1980s by strong immigration of the "poorest of the poor", who had no claims on land or economic opportunities in the overpopulated lowlands. The failure of creating employment in sectors other than agriculture is often blamed for this development (e.g. Hayami 2000). Looking at this history of migration, the closing of land frontiers in the Philippines and the economic situation, the recent strong emigration to other nations seems to be a logical consequence[30]. Considering my data of declining per capita values of HANPP, its components and various types of biomass harvest, it could be argued that the nation is at its biophysical limits and that emigration is a consequence of this.

GDP and HANPP

GDP in the Philippines rose from 3 024 million 1990 US dollars in 1910 to 73 985 in 2000, almost 25 fold. However, this only translates to less than a 3 fold increase of per-capita GDP increase (Table 28). Throughout time, the share of agriculture in GDP (i.e. the primary sector, including forestry and fisheries here) decreased from about 40% before the War to 20% in 2000. Per capita GDP from agriculture stayed more or less constant at around 200 1990 USD.

By showing how many kg DM of HANPP corresponded to a 1990 US dollar of GDP in a certain year, I relate my calculated HANPP values to GDP (Table 28). It could be interesting to compare the values of HANPP per GDP from agriculture with other nations to get a measure of how much monetary revenue is generated from agriculture and forestry per unit HANPP. According to my data in 1910, about 71 kg DM correspond to one 1990 USD of GDP from agriculture; this value decreased over time and was 13.4 kg DM in the year 2000, which could be considered an increase in economic efficiency.

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[30] Migration and remittances are to a certain degree encouraged by the government and institutionalized through the Philippine Overseas Employment Administration (POEA) which was founded in 1982 (http://www.poea.gov.ph/html/aboutus.html, accessed January 20, 2007).

Table 28 GDP total and per capita and the contribution of agriculture in the Philippines for selected years

	1910	1925	1939	1955	1970	1985	2000
GDP [Million 1990 USD]	3 024	6 096	9 582	13 011	26 583	44 302	73 985
In agriculutre	1 149	2 386	3 617	4 280	7 491	10 888	14 635
share agriculture	38%	39%	38%	33%	28%	25%	20%
per capita [1990 USD/cap]	368	523	599	552	721	810	967
In agriculutre	140	205	226	182	203	199	191
HANPP/GDP [kg DM/1990 USD/a]	27.1	16.5	12.7	11.2	6.9	4.2	2.6
HANPP/GDP in agriculture	71.3	42.1	33.6	33.9	24.4	17.2	13.4

Also HANPP per GDP values are presented.

Biomass trade and HANPP

During the time of the Spanish colonial reign major sectors of Philippine agriculture were orientated towards the export market. Tobacco, sugarcane, coconut and abaca are the most prominent examples for these export crops. Under the US reign in the first part of the 20th century, the focus on export was kept up often with exclusive trade between the US and the Philippines (Corpuz 1997). This export orientation of the agriculture was one of the reason why the Philippines became a net importer of rice in he late 19th century and remain so with very few exceptional years until this date[31]. Therefore, biomass trade in the first half of the 20th century mainly consisted of export of sugar, copra and coconut oil and abaca fibre (domestic demand for tobacco made the Philippines a net importer early in the 20th century). Imported biomass consisted to a large degree of the staples rice and wheat. The physical amount of this trade can be seen in Table 29. However, as noted, numbers up to 1961 have to be interpreted carefully. Nevertheless, it can be said that the Philippines were a net exporter of biomass for most of the first half of the 20th century. The biomass trade data from 1961 onwards can be considered to provide a more complete picture since forest products and many minor products were included (source of these data is the FAO 2005).

[31] In fact, one of the aims of placing IRRI in the Philippines was to establish self-sufficiency in rice supply; a goal that could not be established until today. While rice production increased, almost 4-fold from 1960 to 2003, owing to yield increases, net imports also rose again over the last decade.

Table 29 Biomass trade and its share in different HANPP components in the Philippines for selected years

		1910	1923	1938	1952	1961	1970	1980	1990	2000
in Mt DM	export	0.38[1]	0.73[1]	1.54[1]	1.77[1]	5.42	9.04	5.12	2.67	2.02
per year	import	0.17[1]	0.10[1]	n.d.	0.25[1]	0.70	0.87	1.60	3.86	6.96
in % of commercial	export	19.3%	16.9%	20.8%	21.7%	30.7%	34.1%	16.1%	8.6%	6.0%
production	import	8.7%	2.4%	n.d.	3.0%	3.9%	3.3%	5.0%	12.4%	20.7%
in % of	export	1.5%	2.0%	2.9%	3.2%	7.2%	9.5%	5.0%	2.6%	1.8%
ANPPh	import	0.7%	0.3%	n.d.	0.4%	0.9%	0.9%	1.6%	3.8%	6.2%
In HANPP%	export	0.11%	0.21%	0.44%	0.51%	1.56%	2.60%	1.47%	0.77%	0.58%
(share of $ANPP_0$)	import	0.05%	0.03%	n.d.	0.07%	0.20%	0.25%	0.46%	1.11%	2.00%
	HANPP%	23.6%	28.5%	35.2%	38.7%	48.1%	52.5%	54.3%	54.7%	56.3%

[1] Values before 1961 do not contain forest products and a number of minor categories and just should give a picture of the development and in general be interpreted with caution; n.d. no data

The development of trade from 1961 until 2000 provides a remarkable picture. The Philippines were a large-scale net exporter of biomass until the 1980s. In that decade, a shift in its trade structure occurred and by 2000, they showed a rather high net import[32]. Some explanations for this development are (see e.g. Bautista (1990), Shimamoto et al. (2004), Cardeans et al. (2005)):

- As noted before, the 1960s and 1970s were major years for large scale logging with most of the wood sold overseas (note that if illegal logging was considered, the export numbers would most likely be considerably higher). The Philippines were one of the world's leading exporters of tropical timber during those years. With much of the commercial timber gone with the forests, the Philippines have become a net importer of wood and wood products around 1990.
- Population and per capita GDP growth created a stronger domestic demand, e.g. the Philippines are no longer a large scale net exporter of sugar, since its production has been consumed domestically in recent years[33].

[32] It seems that the mentioned emigration in recent years seems to be in a way compensating the shift in the trade balance of agricultural products. The World Bank claims that remittances of Filipino migrants amounted to 11.6 billions USD or 13.5 percent of the Philippine GDP in 2004 (World Bank 2006). Since the 1970s, the export of human labour has become an important aspect of the Philippine economy; with about 10% of the total population abroad in recent years, many families relying on these remittances and many Filipinos aspiring to migrate (mostly temporal) because of economic reasons.

[33] It has to be noted that the Philippine sugar industry suffered from a serious crisis in the 1980s, owing mainly to loss of competitiveness on the world market because of failure in adopting new institutional policies. Also lowered US import quotas and to the decline of world sugar prices had a major impact in the crisis; see e.g. Ha-

- GATT and WTO membership opened the market for cheap feedstuff such as corn and soy beans which recently compromise a significant share of Philippine biomass imports.

Table 29 also gives the share of biomass exports and imports in commercial production, total biomass harvest and in HANPP%. In relation to total commercial production (crops and wood), the export share until recently seems rather high, peaking at over one third in the early 1970s. In 2000, biomass imports reached an amount which was over one fifth of domestic production. Expressing these developments in HANPP% gives a very interesting result, especially looking at the development of 1970 to 2000. According to my data, HANPP% for the Philippines rose from 52.5% to 56.3% by 3.8 percentage points during that time. The trade balance in 1970 is 2.3 HANPP% in favour of the Philippines while the one in 2000 is 1.4 HANPP% at their expense. If – in a thought experiment – these would be incorporated in the HANPP% values, the rise would be from 50.2% to 57.7%, i.e. 3.7 HANPP% more than the actual calculated values; i.e. a doubling of the apparent increase. If one considers that a significant amount of backflows, and probably also $\Delta ANPP_{LC}$ are related to the traded biomass, this difference could well be even higher[34].

Technical energy consumption, fertilizer input and yield development

A rough picture of the development of technical energy consumption in the Philippines can be seen in Table 30. The value for biomass comes from my calculation and estimates. It can be seen that the total consumption increased almost by a factor 10 from 1925 to 2000. The system seems to be dominated by biomass until the 1960s. Per capita biomass consumption decreased substantially over time; this is most likely due to a decrease in readily available wood fuel as forest area declined and also due to the increasing importance of other fuels. Other energy sources are oil (to a large share imported, as for coal) and electricity from hydropower and geothermal plants. The exploitation of geothermal power started in 1977 and rose

yami (1990). However, looking at physical numbers, tonnage production has again reached peak values in the 1990s and is consumed almost entirely locally now.

[34] For example, one could consider part of the $\Delta ANPP_{LC}$ due to deforestation in the Philippines caused by logging operations that generated wood mostly exported from the nation (see above).

strongly since then[35]. Per capita energy consumption also shows an increase since the 1960, rising from 14 GJ per capita and year in 1965 to 24 GJ/cap/a in 2000.

Table 30 Technical energy consumption in the Philippines for selected years (excl. biomass for food and feed)

	1925	**1938**	**1955**	**1965**	**1975**	**1985**	**1995**	**2000**
Coal [PJ/a]	15	9	4	3	3	55	80	220
Oil [PJ/a]	14	21	87	209	443	338	795	767
Gas [PJ/a]	-	-	-	-	-	-	0	0
Primary Electricity [PJ/a][1]	0	0	2	6	9	198	244	448
Biomass [PJ/a]	161	196	262	306	334	374	380	397
total [PJ/a]	190	226	355	524	788	966	1 500	1 832
per capita [GJ/cap/a]	16	14	15	16	19	18	22	24

[1] Primary electricity consists of geothermal energy and hydropower

A high level of external inputs is an important aspect of agricultural intensification. Use of inorganic fertilizer is one of the most common of these inputs. Table 31 gives the development of inorganic fertilizer use for the Philippines and relates it to $ANPP_h$ and the average yields for the staples rice and corn. Unfortunately, I can only provide data on fertilizers from 1961 onwards. However, this corresponds well with what is considered the start of agricultural intensification in the Philippines[36]. No increase in rice and corn yield is visible before 1965 from Table 31. After that year with increasing fertilizer inputs (also per capita), the yields increase drastically and from the present data, no indication can yet be found that the increase is levelling off. With these increased yields, total biomass harvest on farmland rose dramatically, contributing to total HANPP development as already discussed above. Along with fertilizers the use of pesticides also became more and more common in recent decades. These also contribute to increased commercial yields, but are linked to other environmental costs, as fertilizers; these costs include, for example, eutrophication, contamination of food, increased vulnerability to pests, loss of flexibility and risk avoiding ability for the farmers and

[35] The Philippines are the world's second largest producer of geothermal power, owing to a large share to the volcanic nature of the archipelago; International Geothermal Association http://iga.igg.cnr.it/geoworld/geoworld.php?sub=elgen&country=philippines, accessed January 10, 2007

[36] The IRRI released its first rice variety in 1965; fertilizers were promoted to be used along with newly bred varieties since they showed a strong response to fertilization.

biodiversity loss (see, e.g. Bajet and Tejada 1995, Kellman and Tackaberry 1997 and Dobermann and Witt 2000).

Table 31 Development of fertilizer consumption, ANPPh and yields of rice and corn in the Philippines for selected years

	1925	**1938**	**1955**	**1965**	**1975**	**1985**	**1995**	**2000**
inorganic fertilizer consumption [kt/a]	n.d.	n.d.	n.d.	113	227	284	598	735
per capita [kg/cap/a]	n.d.	n.d.	n.d.	3.6	5.4	5.2	8.7	9.6
ANPPh farmland [t DM/ha/a]	2.8	3.1	3.4	3.8	5.1	5.6	6.8	7.4
rice yield [t DM/ha/a]	1.2	1.2	1.2	1.4	2.0	3.7	4.1	4.4
corn yield [t DM/ha/a]	1.1	0.8	0.7	0.9	1.2	1.6	2.2	2.6

Note that yields are per hectare and year, i.e. they consider multi-cropping practices

Synopsis

It has been shown that HANPP in the Philippines increased significantly over the 20th century. Without the inclusion of biomass burned in slash and burn practices, it rose from below 3 t DM/ha/a in the beginning of the 20th century to about 6.5 t DM/ha/a at the turn of the last century; i.e. humans appropriated about 25% and 56% of the potential ANPP, respectively. Considering slash and burn biomass burning, the increase is still almost 2-fold. In any case, in recent decades HANPP is significantly higher than 50% of potential ANPP, meaning that humans, just one species, are using the lion's share of energy available in ecosystems, leaving less than half for other organisms. The increase in HANPP occurred largely until the 1960s. At the end of that decade, a levelling off of total HANPP was observed. This can be related to two phases of agricultural expansion. Up to the 1960s, increase in agricultural output was mainly achieved through expansion of area under permanent cultivation. Yields were typically low and forgone productivity on farmland high, leading to a strong increase in HANPP. Practices of shifting cultivation were probably characterized by increasingly short fallow periods and further increased pressure on the land. Agricultural intensification that set in with the so-called Green Revolution during the 1960s, mainly in lowland rice-producing areas, enabled higher yields on farmland and therefore, facilitated increased biomass harvest with decreased foregone productivity leading to stabilization of total HANPP. This led to a higher efficiency in ANPP appropriation but was linked to a decline in energetic output to input ratios and introduced other environmental costs associated with inorganic fertilization and pesticide use. However, foregone productivity stayed high in the uplands with their secondary degraded vegetation. To this day, the nation is struggling to find proper ways of agriculture in these areas to provide sustainable livelihoods for the upland dwellers, often considered the “poorest of the poor”.

Another element that contributed to the strong increase in HANPP until the late 1960s and its stabilization from the 1970s onward was the development of forest area and the forestry sector. Over the century, the nation faced a dramatic decline in forest cover, from almost 70% to as little as about 20% of total land area. Forest resources were exploited in an unsuitable manner with a distinct peak in wood harvest in the early 1970s; much of this exploitation was not related to local population as most of the unprocessed logs were exported overseas. The land opened by logging operations, however, provided a possibility for migrant farmers from the densely populated lowland areas. Upland farming led to increased soil erosion and degradation problems. Consequently, this process led to increased foregone ANPP in former forested lands. Wood harvest declined sharply since the 1970s and the country became a net importer of wood products in recent years.

Population growth was exceptionally high throughout the whole period, leading to a 10-fold population increase from 1910 to 2003. This development posed a continuous strain on the nation’s natural resources. In fact, before the Green Revolution set off, many regions approached critical limits of population density for a society based mainly on subsistence agricultural. HANPP per capita decreased significantly over time with biomass harvest decreasing at a much lower rate than foregone ANPP, owing to the mentioned increases in efficiency. Of the different components of societal biomass harvest only commercial crop harvest could more or less keep track with population development. However, the country remains a net importer of rice. While having been a large scale net exporter of biomass over most of the past century, the trade balance changed in the 1980s and the nation has imported large amounts of biomass in recent years. This development is mainly owing to the population explosion and to the described forest exploitation. If traded biomass would be considered in the HANPP assessment of the Philippine society, there would, most likely, be no stabilization from the 1970s onwards, owing to the mentioned shift in the trade balance. The importance of biomass in the technical energy mix of the islands until recently was of outstanding importance. Dependence on imported fossil fuel and domestically produced electricity is, however, increasing strongly, leading to the impression that the nation is in the midst of the process of a transition to a different energetic regime.

In the future, further increases in efficiency of ANPP appropriation seem possible, since average yields are still comparably low. Such further intensification is typically linked to public investments, for example, in irrigation and the provision of roads for market access. Such investments are, however, related to the national economic situation. With foreign debt problems, emigration of skilled workers and corruption problems, the situation looks kind of bleak. Provision of off-farm employment and the strengthening of non-agriculture-related sectors of industry and services seem crucial. In the uplands, where ways to practice intensive agriculture are lacking to this day, approaches such as agroforestry seem promising to provide reasonable livelihoods for the population. Intercropping tree crops with subsistence and cash crops can be a way to sustain ecosystem services and provide poverty alleviation at the same time. However, large scale success has yet to be established and market access is crucial. Extensive small scale subsistence agriculture does not seem to be an option at the present high levels of population density and existing links to the world economy. Full integration into global markets, however, should be considered only with high caution, as the option of e.g. cheap wood or rice imports could undermine national goals of reforestation and agricultural self-sufficiency, respectively. In short, the key to increased future biomass harvests, which are necessary as the population continues to grow, seems to be to further intensify the agricultural sectors and find ways to increase the productivity of degraded lands. These developments would be more or less HANPP-neutral and mean further increase in efficiencies. However, the present HANPP levels pose, most likely, a heavy strain to the nation's originally rich biodiversity.

Comparability to other studies is limited to this date, as not many historical HANPP assessments exist. Krausmann (2001) provides a detailed study on the HANPP trajectory in Austria from 1830 to 1995. He concludes that in Austria HANPP decreased and $ANPP_h$ increased through agricultural intensification which led to abandonment of unfavourable farmland and increase in forest area. With the exception of the increase in forest area, the process is similar to the one in the post-Green Revolution Philippines. Other historic HANPP assessments will become available shortly, on global and national levels. This might lead to the possibility to investigate if typical forms of HANPP trajectories exist. The present study focuses on a tropical developing nation, with a colonial history, and input data can often not be considered as reliable as comparable data for developed nations; also the incorporation of slash and burn practices proved difficult and unsatisfactory with available data. Nonetheless, the results of the research should be robust enough to give insights referring to trends and trajectories. They present evidence of a phase in the transition, characterized by the aerial expansion of permanent agriculture, decline of shifting cultivation, shortened fallow periods, closing of the land frontier of permanently cultivable land, and a strong increase in HANPP. With agricultural intensification, productivity per unit area increases through external inputs, and HANPP stabilizes, most likely at other environmental costs. Country specific factors, such as, in the Philippine context, the rapid exploitation of forest resources and migration patterns, are important and need to be considered and discussed.

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Appendix

A digital appendix, consisting of three Microsoft Excel spreadsheets, is included on CD in the hardcopy of my thesis. Here I give a brief description of the files:

- Major input data: the file “appendix1_major_input_data.xls” compiles time series data on crop production, crop area harvested, numbers of livestock, wood production and the proxy data population, GDP, biomass trade and fertilizer-consumption.

- Main factors: the file “appendix2_main_factors.xls” shows factors used for the calculation and assignment of: $ANPP_0$ and $ANPP_{act}$, residues and $ANPP_{act}$ on cropland, livestock feed demand and grazed biomass, forestry residues and biomass burned through human-induced fires.

- Main results: the file “appendix3_main_results.xls” presents major results of my time series assessment of HANPP in the Philippines from 1910-2003. These include: the data set on land use for 11 land use categories; $ANPP_0$, $ANPP_{act}$, and $ANPP_h$ also specified these 11 categories; and human biomass harvest broken down into 10 categories (industrial wood harvest, wood fuel harvest, grazed biomass, biomass burned in slash & burn practices, biomass burned in other fires, biomass residues used as fuel, biomass residues used as feed, biomass residues backflow, biomass residues burned, biomass residues other uses). A detail description on how the presented items were calculated can be found in the section “Methods, Materials and Data Sources” of this publication.

The files, along with more detailed data and information can be requested from the author via e-mail.