LEGATO

RICE ECOSYSTEM SERVICES

Land-use intensity and Ecological EnGineering –
Assessment Tools for risks and Opportunities
in irrigated rice based production systems

LEGATO Schlussbericht PIK

Erstellt von:
Fanny Langerwisch, Kirsten Thonicke

Beteiligte Wissenschaftler:
Dr. Kirsten Thonicke (PI), Dr. Fanny Langerwisch, Dr. Paulo Oliveira

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I Kurzdarstellung

I.1 Aufgabenstellung

Die Untersuchung der Auswirkungen von Klima- und Landnutzungswandel auf Agrarsysteme in Südostasien ist von entscheidender Bedeutung für die nachhaltige Entwicklung in dieser Region. Als Teil des LEGATO-Projekts gehörte es zu den Hauptaufgaben des PIKs Klima- und Landnutzungsszenarien für alle Projektpartner zur Verfügung zu stellen bzw. zu entwickeln. Weiterhin sollten die Auswirkungen des globalen Wandels auf die Verfügbarkeit/Bereitstellung von verschiedenen Ökosystemdienstleistungen, wie zum Beispiel Reisertrag, Kohlenstoff-Aufnahme und –Speicherung, mit dem dynamischen Vegetations- und Hydrologie-Modell LPJmL abgeschätzt werden.

I.2 Voraussetzungen, unter denen das Projekt durchgeführt wurde

Bei LEGATO handelt es sich um ein Verbundprojekt, das im Rahmen des BMBF-finanzierten Förderschwerpunkts "Sustainable land management" (Module A: "Interaction between land management, climate change and ecosystem services") realisiert wurde. Die Koordination lag beim Helmholtz-Zentrum für Umweltforschung. Beteiligt waren außerdem weitere Projektpartner aus den Philippinen und Vietnam sowie eine Reihe an assoziierten Projektpartnern. Eine vollständige Liste der beteiligten Partner findet sich auf der Projekt-Homepage http://www.legato-project.net. Eine Auflistung der Partner, die insbesondere wichtig für die Arbeit des PIK waren, ist unter Punkt ‚Zusammenarbeit mit anderen Stellen‘ zu finden.

I.3 Planung und Ablauf des Projektes

Das Projekt war auf zunächst für eine Dauer von fünf Jahren angelegt. Es startete am 01.03.2011 und endete nach einer kostenneutralen Verlängerung am 31.10.2016. Der genaue Ablaufplan ist in der Vorhabenbeschreibung („Description of Work“ Anhang B) dargelegt, die der fördernden Institution vorliegen.

I.4 Wissenschaftlich-technischer Stand, an den angeknüpft wurde

Die Arbeit des PIK im LEGATO-Projekt konnte auf einer Reihe von Vorarbeiten insbesondere in der Modellentwicklung von LPJmL und der Klimadatenaufbereitung aufbauen.

I.5 Zusammenarbeit mit anderen Stellen

Wir arbeiteten vorrangig mit den Hauptprojektpartnern und assoziierten Partnern zusammen, wie esim Rahmen des Projektes vorgesehen war. . Innerhalb des Projekts arbeitete das PIK hauptsächlich mit folgenden Partnern zusammen: Zusammenarbeit mit Benjamin Burkhard (CAU) zur Identifikation von Indikatoren für Ökosystemdienstleistungen und die gemeinsame Betreuung von Masterstudentin (Shanghua Li, CAU) über „Human Appropriation of Net Primary Production“. Kollaboration mit Stefan Hotes (Universität Marburg), Monina Escalada (IRRI/VSU), Vera Tekken (Universität Greifswald), Joachim Spagenberg (UFZ), Ho Van Chien (IRRI/MARD) und Tomas Vaclavik (GLUES, UFZ) zur Entwicklung der hochaufgelöste Landnutzungsszenarien, deren Narrative aus Experteninterviews als raumzeitlich explizite Datensätze entwickelt worden waren.

II Eingehende Darstellung

II.1 Ergebnisse

Wissenschaftliche Ergebnisse – Teilziel 1: Aufarbeitung und Bereitstellung kleinskaliger Klimadaten

Innerhalb des Projektes wurden vom PIK kleinskalige Klimaszenarien (Gridzellgröße von 30mx30m bei täglicher Auflösung) aus GCM-basierten und bias-korrigierten Klimaszenarien für die LEGATO-Standorte erstellt. Diese Klimaszenarien wurden unter anderem für die Vegetationsmodellierung zur Berechnung landwirtschaftlicher Erträge und verschiedener Ökosystemdienstleistungen benötigt. Von den beteiligten Wissenschaftlern des PIK wurde eine Skalierungsmethode entwickelt (beschrieben in Langerwisch et al., under revision, ERL), die die Ansätze “inverse distance interpolation“ (Shepard, 1968) und „lapse-correction“ (Olea, 1999) kombinierte, um aus Klimaszenarien mit einer räumlichen Auflösung von 0.5°×0.5° lat/lon, Daten mit einer Auflösung von 30×30m zu erstellen. Die Ergebnisse der Skalierung wurden umfassend mit Messdaten validiert. Hierzu wurden Vor-Ort-Messungen für Niederschlag und Temperatur von 25 Standorten nahe der Untersuchungsgebiete verwendet. Die validierte Methode wurde für Klimaszenarien der 19 Globalen Zirkulationsmodelle, soweit sie verfügbar waren, für 3 Emissionsszenarien (SRES, Nakićenović et al., 2000) angewendet.. Dadurch konnten den LEGATO-Projektpartnern 52 Klimaszenarien zur Berechnung möglicher Klimafolgen in den LEGATO-Standorten zur Verfügung gestellt werden (LEGATO Deliverable 1.2.2).

Wissenschaftliche Ergebnisse – Teilziel 2: Entwicklung von regional spezifischen Landnutzungsszenarien

Für die Abschätzung der zukünftigen Entwicklung landwirtschaftlicherer Erträge und der Bereitstellung von Ökosystemdienstleistungen wurden auf die LEGATO-Standorte abgestimmte Landnutzungsszenarien benötigt. Diese Szenarien wurden auf Grundlage von a) Experteneinschätzungen aus der Region und b) des DART-BIO-Modells der Weltökonomie (Calzadilla et al., 2014) entwickelt. Durch die Experteneinschätzungen aus den jeweiligen LEGATO-Untersuchungsgebieten wurden realistischere Abschätzungen ermittelt, die die Entwicklung von Siedlungsflächen, Reis- und anderen Feldfruchtflächen, sowie Waldflächen vorgaben. Diese Experteneinschätzungen wurden genutzt um zeitliche Entwicklungen in linear interpolierte Trends für jeden LEGATO-Standort separat zu übersetzen. Diese zeitlichen Trends wurden anschließend mit Hilfe eines GIS in räumliche Muster übersetzt und damit in die Fläche extrapoliert. Die Methoden wurden in Langerwisch et al. (in revision, ERL) beschrieben.

Wissenschaftliche Ergebnisse – Teilziel 3: Abschätzung der Bereitstellungen verschiedenen Ökosystemdienstleistungen in den Untersuchungsgebieten unter zukünftigem Landnutzungs- und Klimawandel

Die Arbeiten zur Erreichung dieses wissenschaftlichen Ziels konnten auf die (methodischen) Vorarbeiten der vorrangegangenen Teilziele aufbauen. Es wurden die hochaufgelösten Klimaszenarien und die Landnutzungsszenarien genutzt, um mit dem dynamischen Vegetations- und Hydrologie-Model LPJmL Zukunftssimulationen durchzuführen. Zur Validierung der Modellergebnisse wurden Beobachtungsdaten zu landwirtschaftlichen Erträgen von Reis für den Zeitraum 2011-2014 genutzt, die von Anika Klotzbücher (geb. Marxen) und Thimo Klotzbücher (UFZ) zur Verfügung gestellt wurden. Weiterhin wurden Projektionen zu zukünftigen Entwicklung des landwirtschaftlichen Ertrags, der Wasserverfügbarkeit, und der Aufnahme und Speicherung von Kohlenstoff unter Verwendung des LPJmL-Modells vorgenommen. Diese wurden jeweils unter Berücksichtigung der lokalen Klima- und Landnutzungsszenarien für die jeweiligen LEGATO-Standorte ermittelt. Die Ergebnisse sind in Langerwisch et al. (in revision, ERL) beschrieben bzw. werden in Langerwisch et al. (in preparation) publiziert.

II.2 Wichtigste Positionen des zahlenmäßigen Nachweises

Die im Projekt angestellten bzw. aktiven Personen, die hauptamtlich im Projekt gearbeitet haben, sind in Tabelle 1 gelistet (Summe der Personenmonate: 57,25).

Tabelle 1

Person	Personenmonate	Hauptaufgaben
K. Thonicke (PI)	-	Konzept- und Methodenentwicklung
F. Langerwisch	38,5	Szenarienentwicklung, Datenaufbereitung, Durchführung der Modellsimulationen, Auswertung, Teilnahme an Jahrestreffen, Präsentation der Ergebnisse auf internationalen Treffen, Verfassen von Berichten und Publikationen
P. Oliveira	4,7	Datenaufbereitung, Teilnahme an Projekttreffen

Die in Tabelle 1 aufgelisteten Personen haben an den Projekttreffen und weiteren internationalen Veranstaltungen teilgenommen. Die wichtigsten Veranstaltungen sind in Tabelle 2 aufgelistet.

Tabelle 2

Veranstaltung	Datum	Ort	Person
Auftakttreffen	09.-11.05.2011	Halle/Saale	K. Thonicke
‚Planet under Pressure' Konferenz	25.-30.03.2012	London (Großbritannien)	F. Langerwisch
LEGATO-Jahrestreffen	30.06.-08.07.2012	Banaue (Philippinen)	F. Langerwisch
GfÖ Konferenz	10.-12.09.2012	Lüneburg	P. Oliveira
LEGATO-Jahrestreffen	09.-17.04.2013	Hanoi (Vietnam)	P. Oliveira
LEGATO-Jahrestreffen	08.-21.03.2014	Ho Chi Minh (Vietnam)	P. Oliveira
LEGATO-Jahrestreffen	08.-21.03.2014	Ho Chi Minh (Vietnam)	F. Langerwisch
ESP Konferenz	01.-13.09.2014	San José (Costa Rica)	F. Langerwisch
‚Biodiversity and Food Security' Konferenz	29.-31.10.2014	Aix-en-Provence (Frankreich)	F. Langerwisch
LEGATO-Jahrestreffen	18.-29.03.2015	Yogyakarta (Indonesien)	F. Langerwisch
PECS + ESP Konferenzen	01.-18.11.2015	Stellenbosch (Südafrika)	F. Langerwisch
LEGATO-Abschlusskonferenz	02.-13.08.2016	Banaue (Philippinen)	F. Langerwisch

II.3 Notwendigkeit und Angemessenheit der geleisteten Arbeit

Die Notwendigkeit der Zuwendung ergab sich aus dem hohen Arbeitsaufwand bei der Erstellung der Klimadaten, der Entwicklung der Landnutzungsszenarien und der Analyse der Simulationsergebnisse. Es standen keine Mittel aus anderen Quellen zur Verfügung.

II.4 Voraussichtlicher Nutzen und Verwertbarkeit der Projektergebnisse

Die im Rahmen des Projektes LEGATO produzierten Ergebnisse tragen wesentlich sowohl zur Weiterentwicklung wissenschaftlicher Fragestellungen als auch zur Umsetzung neuer Konzepte bei. Die wichtigsten Anwendungsmöglichkeiten können wie folgt zusammengefasst werden:

Wissenschaft

1) Ergänzte Datensätze zur Klima- und Landnutzungswandel können zur Spezifizierung bestehender Abschätzungen durch Modelle verwendet werden.
2) Die in LEGATO erstellten Datensätze tragen dazu bei, die Reaktion der Flora und Fauna auf Klima- und Habitatveränderungen besser abzuschätzen.
3) Analysen der Beziehungen zwischen klimatischen Veränderungen und der Vegetationsdynamik helfen, die Effekte rezenter Klimaveränderungen auf Ökosystemdienstleistungen zu verstehen, um damit die Auswirkungen zukünftiger Klima- und Landnutzungsänderungen besser abschätzen zu können.

II.5 Während der Durchführung des Projektes dem Auftragnehmer bekannt gewordener Fortschritt auf dem Gebiet des Projektes bei anderen Stellen

Soweit uns bekannt (auch durch entsprechende Literaturrecherche) gab es auf dem Kerngebiet des Projektes keine weiteren relevanten Studien, bei denen nicht auch LEGATO-

Konsortialmitglieder beteiligt gewesen wären. Allgemein gab es natürlich im Forschungsbereich zum globalen Wandel bezüglich der Auswirkungen auf Ökosystemdienstleistungen zahlreiche Arbeiten, die aber nicht in Konkurrenz zu uns sondern allenfalls komplementär zu sehen sind.

II.6 Erfolgte und geplante Veröffentlichungen

Die aus dem Projekt resultierenden Ergebnisse wurden auf internen Projekttreffen und auf internationalen Konferenzen präsentiert. Die entsprechenden Vorträge sind im Folgenden aufgelistet. Die bereits in wissenschaftlichen Artikeln veröffentlichten Ergebnisse sowie die zur Publikation vorbereiteten Manuskripte sind im Anschluss aufgelistet.

<u>Vorträge</u>

Langerwisch F., Václavík T., von Bloh W., Konzmann M., Sakschewski B., Thonicke K. (2016) The potential of land use change to offset climate change impacts on the provision of ecosystem services - A modelling study. Talk. GLP 3rd Open Science Meeting. 24th-27th October 2016. Beijing (China).

Langerwisch F., Václavík T., von Bloh W., Konzmann M., Li S., Thonicke K. (2016) Projected provision of ecosystem services, trade-offs and synergies in the LEGATO areas. Talk. Final LEGATO Conference. 06th-09th August 2016. Banaue (Philippines).

Langerwisch F., von Bloh W., Sakschewski B., Konzmann M., Václavík T., Thonicke K. (2015) Projected provision of ecosystem services in rice producing systems in Southeast Asia under land-use and climate change. Talk. ESP Conference. 9th-13th November 2015. Stellenbosch (South Africa).

Langerwisch F., von Bloh W., Sakschewski B., Konzmann M., Gaedke-Merzhäuser L., Václavík T., Thonicke K. (2015) Future changes in the provision of ecosystem services in Southeast Asia under climate and land-use scenarios. Talk. PECS Conference. 3rd-5th November 2015. Stellenbosch (South Africa).

Langerwisch F., von Bloh W., Sakschewski B., Konzmann M., Li S., Václavík T., Thonicke K. (2015) Future changes in the provision of ecosystem services. Talk. Annual LEGATO Conference. 19th-24th March 2015. Yogyakarta (Indonesia).

Langerwisch F., von Bloh W., Sakschewski B., Oliveira P., Boit A., Thonicke K. (2014) Bundling ecosystems services from forests and rice fields in Southeast Asia under climate and land-use change. Talk. 7th Annual ESP Conference. 08th-12th Sep 2014. San José (Costa Rica).

Langerwisch F., von Bloh W., Sakschewski B., Oliveira P., Thonicke K. (2014) Assessing the local carbon and water dynamics with LPJmL. Talk. Annual LEGATO Conference. 10th-16th March 2014. Ho Chi Minh City (Vietnam).

Oliveira P., Langerwisch F., von Bloh W., Thonicke K. (2014) Preparation of small scale climate data from global GCMs to investigate future development of local climate. Talk. Annual LEGATO Conference. 10th-16th March 2014. Ho Chi Minh City (Vietnam).

Oliveira P., Langerwisch F., Thonicke K. (2014) Simulation of vegetation dynamics and nutrient fluxes in Southeast Asia rice agro-ecosystems using LPJmL. Talk. Annual LEGATO Conference. 8th-16th April 2013. Hanoi (Vietnam).

Langerwisch F., Václavík T. (2012) Scenarios and Modelling. Talk. Annual LEGATO Conference. 1st-7th July 2012. Banaue (Philippines).

Masterarbeit

Li S. Quantifying Human Appropriation of Net Primary Production (HANPP) in a rice-based agricultural landscape in the Sa Pa region, Vietnam, 1993 to 2050.

Publikationen

Langerwisch F., von Bloh W., Sakschewski B., Václavík T., Boit A., Thonicke K. (in preparation). Adaptation of vegetation to future climate change in highland sites in Southeast Asia. Special Issue in Paddy and Water Environment.

Spangenberg J.H., Beaurepaire A.L., Bergmeier E., Burkhard B., Chien H.V., Cuongh L.Q., Görg C., Grescho V., Hai L.H., Heong K.L., Horgan F.G., Hotes S., Klotzbücher A., Klotzbücher T., Kühn I., Langerwisch F., Marion G., Moritz R.F.A., Nguyen Q.A., Ott J., Sann C., Sattler C., Schädler M., Schmidt A., Tekken V., Thanh T.D., Thonicke K., Türke M., Václavík T., Vetterlein D., Westphal C., Wiemers M., Settele J. (under revision) Cross-disciplinary research results integrated into an ecosystem service framework The LEGATO example of integrating research results from the analysis of global change impacts and social, cultural and economic system dynamics of irrigated rice production. Paddy and Water Environment.

Langerwisch F., Václavík T., von Bloh W., Vetter T., Thonicke K. (under revision). Combined effects of climate and land use change on the provision of ecosystem services in rice agro-ecosystems. Environmental Research Letters.

Li S., Langerwisch F., Vu K. C., Burkhard B. (under revision) Quantifying Human Appropriation of Net Primary Production (HANPP) in a rice-based agricultural landscape in the Sa Pa region, Vietnam, 1993 to 2050. Ecological Economics.

Langerwisch F, von Bloh W, Sakschewski B, Václavík T, Boit A, Thonicke K. Langerwisch Adaptation of vegetation to future climate change in highland sites in Southeast Asia. In preparation.

Václavík T., Langerwisch F., Cotter M., Fick J., Häuser I., Hotes S., Kamp J., Settele J., Spangenberg J. H. and Seppelt R. (2016) Investigating potential transferability of place-

based research in land system science. Environmental Research Letters, doi: 10.1088/1748-9326/11/9/095002.

Liste der Deliverables mit PIK-Beteiligung

Tabelle 3

WP No	Milestone / Deliverables
1.2 *	List of data and scenario requirements of project partners, in particular those to be derived from local stakeholders (internal report)
1.2 *	Report of regional evaluation of global data sets and locally available data from interviews back to GLUES (internal report)
1.2 *	Report of specific needs on regional climate and land use change data in the best-case method for interpolation and model to be used, link to local experiences and available information (internal report, together with UFZ)
1.2 *	Documentation of consistent climate and land use scenarios at the required spatial resolution for medium- and long-term projections provided for LEGATO from GLUES GDI (internal report)
2.4	Draft document describing the relationship between ecosystem services and climate. (public report)
3.2	Draft document on the synthesis of results from M 3.2.3.1, region specific climate change scenarios and land use and water supply changes with suggestions for integration in concepts on sustainable land use (public report, together with UMAR)
4.2	Report on the qualitative assessment of integrity and ecosystem services (Hypothesis paper and maps) (internal report)
4.2	Strategy paper on indicator-model-linkages (with WP 4.4) (internal report, together with CAU)
4.2	Literature review on applied resilience and adaptability concepts (public report)
4.2	Documentation of scenario calculation results (Resilience and adaptability of LEGATO indicators) (internal report)
4.3	Comparative documentation of the human-environmental interaction types in the case study areas on the basis of data gathered earlier WPs, using the CBD/IUCN ecosystem management principles (public report)
4.3	Workshop on response functions between the elements of the model components Pressure – State and Impact – Human well-being (internal WS)
4.3	Joint scientific paper on ecosystem service footprints/HANPP analysis (public report)
4.4 *	Agreement with stakeholders and local experts on feedbacks between surrounding landscape and agricultural systems (internal report)
4.4 *	Summary of feedbacks between surrounding landscape and agricultural systems which will be considered in modeling framework (public report)
4.4 *	Implementation of feedbacks in LPJmL and analysis of the role of feedback mechanisms for agricultural production (incl. water provision) (internal 'other')
4.4 *	Analysis of the impacts climate change and potential buffer mechanisms of the surrounding landscape on agricultural production (internal report)
4.4 *	Documentation of impacts climate change and potential buffer mechanisms of the surrounding landscape on agricultural production (public report)

*PIK lead

Liste der Abkürzungen der beteiligten Institute bzw. Projekts

PIK	Potsdam Institut für Klimafolgenforschung
CAU	Christian Albrecht University of Kiel
IRRI / VSU	International Rice Research Institute / Visayas State Univ., Baybay Philippines
IRRI / MARD	International Rice Research Institute / Vietnamese Academy of Agricultural Sciences, Ho-Chi-Minh City, Vietnam
UFZ	Helmholtz-Centre for Environmental Research
GLUES	Koordinationsprojekt, 'Global Assessment of Land Use Dynamics, Greenhouse Gas Emissions and Ecosystem Services'

Referenzen

Calzadilla, A., Delzeit, R. and Klepper, G.: DART-BIO: Modelling the interplay of food, feed and fuels in a global CGE model, Kiel Working Paper, Kiel Institute for the World Economy, Kiel, Germany. [online] Available from: https://www.ifw-members.ifw-kiel.de/publications/dart-bio-modelling-the-interplay-of-food-feed-and-fuels-ina-global-cge-model/KWP1896.pdf., 2014.

Nakićenović, N., Davidson, O., Davis, G., Grübler, A., Kram, T., Lebre La Rovere, E., Metz, B., Morita, T., Pepper, W., Pitcher, H., Sankovski, A., et al.: IPCC Special report on emission scenarios, [online] Available from: http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=0, 2000.

Olea, R. A.: Geostatistics for engineers and earth scientists, 1st ed., Springer US., 1999.

Shepard, D.: A two-dimensional interpolation function for irregularly-spaced data, pp. 517–524, ACM Press. [online] Available from: http://portal.acm.org/citation.cfm?doid=800186.810616 (Accessed 23 September 2016), 1968.

Anhang B

BMBF funding measure
"Sustainable land management"

Module A: "Interaction between land management, climate change and ecosystem services"

Description of Work

(contract version 16th May 2011)

LEGATO

Land-use intensity and **E**cological En**G**ineering –
Assessment **T**ools for risks and **O**pportunities
in irrigated rice based production systems

Project duration: 1. March 2011 – 29. February 2016

Coordination:

Josef Settele, Ingolf Kühn, Stefan Klotz, Joachim Spangenberg
Helmholtz Centre for Environmental Research – UFZ, Germany

Table of Content

1. LEGATO partnership (May 2011)

Acronym	Organisation Name	Scientists involved
	German Partners	
UFZ	Helmholtz-Centre for Environmental Research	Josef Settele, Harald Auge, Walter Durka, Markus Franzen, Volker Grescho, Christoph Görg, Alexander Harpke, Stefan Klotz, Ingolf Kühn, Jürgen Ott, Martin Schädler, Oliver Schweiger, Ralf Seppelt, Joachim Spangenberg, Doris Vetterlein
CAU	Christian Albrecht University of Kiel	Felix Müller, Benjamin Burkhard
UGOE	Georg-August-University of Göttingen	Catrin Westphal, Erwin Bergmeier, Stefan Scheu, Teja Tscharntke, Stefan Vidal
LUPO	LUPO EIA, Trippstadt	Jürgen Ott (for utilisation of project results)
MLU	Martin-Luther-University of Halle-Wittenberg	Reinhold Jahn, Robin Moritz
OLANIS	OLANIS, Leipzig	Thomas Meyer, Volker Grescho
PIK	Potsdam Institute for Climate Impact Research	Kirsten Thonicke, Britta Tietjen, Wolfgang Cramer
S4Y	Science4you, Bonn	Norbert Hirneisen
TUM	Technical University of Munich	Wolfgang Weisser, Manfred Türke
UGR	University of Greifswald	Susanne Stoll-Kleemann, Vera Tekken
UMAR	University of Marburg	Roland Brandl, Stefan Hotes
	South-East Asian Partners	
IRRI	International Rice Research Institute, Los Banos, Philippines	Kong Luen Heong, Finbarr Horgan
IRRI/ MARD	Vietnamese Academy of Agricultural Sciences, Ho-Chi-Minh City, Vietnam	Ho Van Chien, Nguyen Huu Huan
IRRI/VSU	Visayas State Univ., Baybay Philippines	Monina Escalada
CABI	CABI Southeast & East Asia, Malaysia	Wai-Hong Loke, Keng-Yeang Lum
CEPSTA	Center for Policy Studies and Analysis, Hanoi, Vietnam	Dao Thanh Truong, Vu Cao Dam, Nguyen Thi Kim Hoa, Trinh Van Tung, Tong Van Chung, Dang Kim Khanh Ly
IEBR (VAST)	Vietnam Academy of Science and Technology, Hanoi, Vietnam	Le Xuan Canh, Nguyen Van Sinh, Ha Quy Quynh
MARDI	Malaysian Agricultural Research and Development Institute, Malaysia	Mohd Norowi Hamid, Jamal Othman
PhilRice	Philippine Rice Research Institute, Munoz, Philippines	Gertrudo S. Arida
	Other Partners	
BIOSS	Biomathematics & Statistics Scotland, UK	Glenn Marion, Adam Butler, Helen Kettle
PENSOFT	PENSOFT Publishers, Sofia, Bulgaria	Lyubomir Penev, Pavel Stoev, Teodor Georgiev
UAB	Autonomous University of Barcelona, Barcelona, Spain	Joan Martinez Alier, Giuseppa Munda, Beatriz R.-Labajos

2. Summary of the project

LEGATO: **L**and-use intensity and **E**cological En**G**ineering – **A**ssessment **T**ools for risks and **O**pportunities in irrigated rice based production systems

In order to advance long-term sustainable development of intensive land use systems, against risks arising from multiple aspects of global change, LEGATO plans to quantify the dependence of ecosystem functions (ESF) and the services (ESS) they generate in agricultural systems in South East Asia. The focus is on local as well as regional land use intensity (including the socio-cultural and economic background) and biodiversity, and the potential impacts of future climate and land use change.

Following the framework of the Millennium Ecosystem Assessment (MEA), we define supporting services as ESF and deal with selected characteristic elements of the 3 service strands defined by the MEA: a) Provisioning (PS): nutrient cycling & crop production (including consequences for the hydrosphere); b) Regulating (RS): biocontrol & pollination; c) Cultural Services (CS): cultural identity & aesthetics. Studies are planned in three countries of South-East Asia (The Philippines, Vietnam, Malaysia), in landscapes along a gradient reflecting changing geo-climatic and land use intensity, and where possible also cultural conditions. Focus will be on landscapes shaped by irrigated rice. In particular it intends to investigate the interactions between the rice crops and the surrounding landscapes in the light of ecological engineering (as an emerging discipline, concerned with design, monitoring and construction of ecosystems). The overall objective is the elaboration and testing of generally applicable principles within the frame of ecological engineering.

LEGATO will develop valuations of ESS through monetary and non-monetary methods. The most meaningful monetary costs to be calculated are (potential) damage costs (e.g. due to production losses, influences of reduced water quality), management/repair costs (regulation), and avoidance cost (precautionary measures) as these manifest themselves in real markets. Non-monetary costs are crucial for cultural services.

LEGATO will test and improve already existing indicators for ESF/ESS and their values - building upon but going beyond existing indicators sets like those of the CBD (Convention on Biological Diversity) and the SEBI (Streamlining European Biodiversity Indicators). Beyond the applicability of the existing ones, specific integrative indicators for each of the three strands will be tested for their suitability, e.g., the “Human Appropriation of Net Primary Productivity – HANPP” (PS strand); the diversity of indicator plants (incl. weeds), pollinators, and natural enemies of crop pests (RS); and the diversity of charismatic species of conservation concern such as damsel- or dragonflies (CS). Indicator research will be done on intra-, trans- and superregional scales via cross continental comparisons. The DPSIR scheme popularised by the EEA complemented by a drivers' institutional hierarchy analysis as developed in the ALARM project will be applied to illustrate the interaction of the economic and socio-cultural factors with geo-biogenic ones in shaping landscapes and ESS provision and recognition.

As core output, LEGATO will develop guidelines for optimising ESF/ESS given the local socio-cultural conditions and their stabilisation under future climate and land use change, which will particularly affect South and Southeast Asia. There is a clear need for crop productivity increases and diversification. LEGATO will analyse the potential of ecological engineering to achieve this, and test its implementation and transferability across regions (a critical question in particular with regard to the diverse socio-cultural factors). The latter is to be achieved through inclusion e.g., of local agricultural agencies and extension services as partners. Implementation will include assessments of ESS risks and opportunities in the light of changes in land use intensity, biodiversity and climate.

3. Objectives of the project

LEGATO plans to

1. investigate the interactions between **rice cropping systems,** the **landscapes** in which they are imbedded, and the **socio-cultural perceptions and valuation** of both the landscapes and the agricultural practices;
2. quantify (incl. the assessment of uncertainty) the current and future dependencies of ecosystem functions (ESF) & services (ESS) of these cropping systems on local & regional **land use intensity and its driving forces**, **biodiversity**, **climate** and **socio-economic and cultural drivers/constraints**;
3. study three ESF/ESS strands: **nutrient cycling & crop production** (including consequences of water budget and quality; provisioning service = PS), **crop related biocontrol & pollination** (regulating service = RS), and **agricultural landscape related cultural identity & aesthetics** (cultural service = CS) and their feedbacks with the driving forces behind pressures resulting from land use intensity;
4. **develop valuations** and respective integrative indicator sets of the investigated ESF/ESS strands through monetary as well as non-monetary methods, and evaluate their relevance for the provision of the different ESS;
5. test and further improve already existing **indicators** for ESF/ESS and their values and develop and/or test new ones where appropriate and necessary on intra-, trans- and superregional scales via a **cross national comparison**;

6. develop an **indicator based assessment of risks and opportunities** of crop production in the light of ESF/ESS impacted or enhanced through changes in land use intensity, socio-cultural conditions, biodiversity and climate change;
7. develop **guidelines** for decision makers (incl. farmers) and **test their implementation** in order to further enhance ESF/ESS provision, in particular through **ecological engineering**;
8. develop socio-economic analytical frameworks & tools for promotion of advanced land management practices, based on analyses of driving forces & stakeholders (see step 2).
9. build a basic framework for **motivating laymen** to assist in data gathering on biodiversity data for pest control and support for the assessment of risks and opportunities. The framework on which LEGATO builds consists of organisational structures and the technical backbone to manage citizen science data.

4. Specific contribution of the project to the funding goals of the call[1]

LEGATO is designed to contribute to sustainable land management and to fulfil the general conditions of the call e.g., by strengthening cooperation between science, practice (planners and farmers) and business through a good balance in its partnership. The entire setup of the project (Figs. 6.2, 6.3) aims at interdisciplinary integration and transdisciplinary research and the "generation of knowledge which can be used directly by people in the regions" (see WP 5), e.g., through direct involvement of regional and local stakeholders (see WPs 1 and 5).

LEGATO work is region-based due to the reasons explained in the call. As the "solutions offered by the projects must be of a model nature, i.e., they must be transferable to other regions", LEGATO opts for the cross-national approach which includes 3 countries and several Areas of Investigation, as a feasible way to test transferability. The region is call-relevant, as it is a) highly dynamic growth regions (Malaysia, Vietnam), b) affected by demographic change (Philippines), c) mountainous (Philippines, Vietnam), or d) prone to climate change (extremely water dependant irrigated rice areas in Asia).

LEGATO will contribute substantially to the visibility of German research. The fact that we could mobilise international expertise on a high scientific level is reflected in the LEGATO partnership. Our European integration enables trans-regional comparisons. These are enhanced through links to many further research initiatives, which partly are covered through the inclusion of some European teams (e.g., UAB, BIOSS). The consortium – through its scientific excellence and its close links to highly relevant stakeholders – thus should be able to provide adequate answers to the complex questions asked in the call. As the links to many

[1] Literal citations within chapter 4 are from the BMBF call text; highlights/underlines by LEGATO

stakeholders of many research groups involved are already established for one to two decades, LEGATO can convincingly claim the viability of international cooperation with researchers and decision-makers in the study regions.

LEGATO considers all topics listed under points 1 to 5 in the A.2 call text: 1) Method development for analysis (e.g. WPs 2 & 3) and evaluation (WP 4.1 & 4.2); 2) Studies on dependence of ESF and ESS on biodiversity (WP 2 & 3, task 2), climate change (WP 2 & 3, task 3) and land management (WP 2 & 3, task 1); 3) Cumulative and particularly transregional substitution effects are a core element of WP 2 (trait analysis in task 2) under LEGATO's cross-continental approach; 4) land management and other goals (entire project); and 5) Development of socio-economic tools for consideration of ESF/ESS in land management (WP 5).

LEGATO expects to provide answers to the central questions of: a) regional level data collection through application and/or development of standard protocols and trait based analyses (within WP 2s and 3 in close interaction with WP 1); b) interactions and feedback (core part of LEGATO for rice based cropping systems); c) trade-offs and synergies in space through cross-national analyses and time through scenarios of future changes; d) monetary and other assessments (WP 4); e) conditions and tools to optimise ESF/ESS in land use decisions through WP 5, particularly through the Ecological Engineering approach.

LEGATO does not include specific European components which would make it eligible for EU funding.

5. State of the art, applicants' own work to date, economic importance

5.1 State of the art

5.1.1 Overview

LEGATO analyses and evaluates ESF/ESS, both in isolation and in concert, as well as their interaction with economically and socio-culturally determined land use patterns in production systems of annual plants as the core issues to be considered. To be able to do this, LEGATO employs the conceptual framework of the Millennium Ecosystem Assessment (Fig. 5.1).

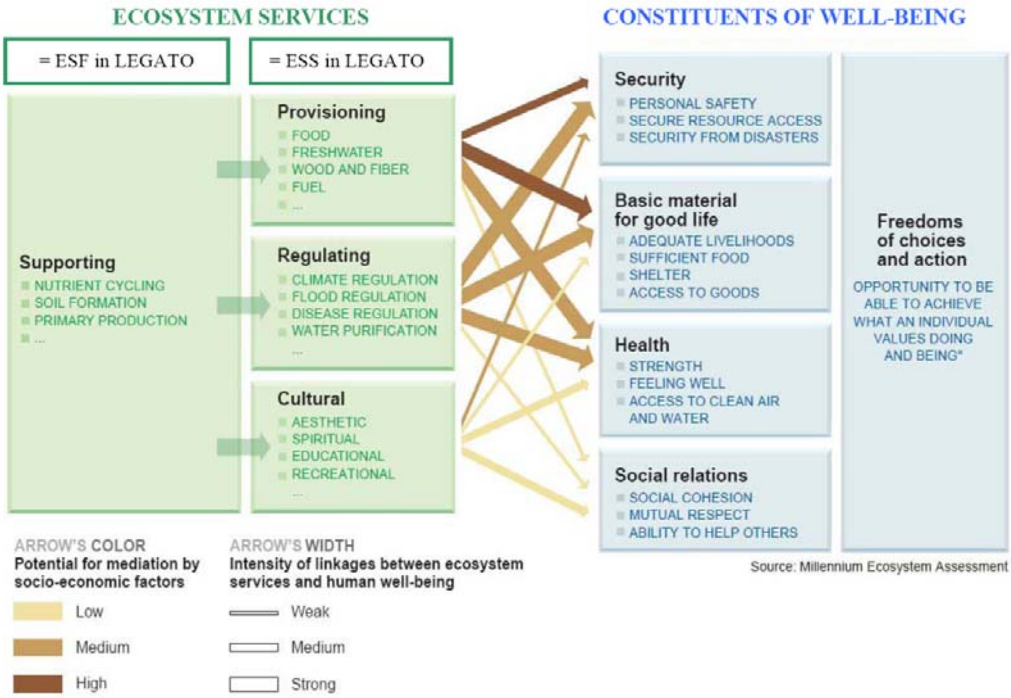


Figure 5.1: Classification of and conceptual connection between ecosystem services and human well-being (from MEA 2005; slightly modified)

Rather than considering all of these elements simultaneously, we have chosen a subset of ecosystem functions and services which are particularly relevant for these cropping systems and which depend in particular on, and/or are impacted by, land use intensity, habitual patterns of land perception and use, biodiversity, and global change. The MEA baseline is “supporting services” (which regulate ecosystems and are of indirect use for humans; e.g. "nutrient cycling” or “primary production"). Within LEGATO we define supporting services as ESF which translate into one of three ESS categories as soon as the human usage comes in:

- **Strand 1 (PS**; Provisioning Services): ESF: Primary production/nutrient cycling
  => ESS: Crop Production/Water Provision/Prevention of Nutrient Loss;
- **Strand 2 (RS**; Regulating Services): ESF: Biodiv/food-web structure/pollination
  => ESS: Biocontrol of Crop pests/Crop pollination;
- **Strand 3 (CS**; Cultural Services): ESF: Landscape morphology/species pool
  => ESS: Cultural Identity & Aesthetics.

Within LEGATO we will investigate the positive or negative feed-back effects between functions and services with one example of each of these categories (Fig. 5.1). Further, there are not only feed-back mechanisms between these strands but also of these strands with ecological engineering. In cooperation with the analytic framework for ESS tradeoffs developed within the GLUES project, this analysis allows us to consider the merits of promoting one particular ESF/ESS in terms of the effects this will have on other ESS.

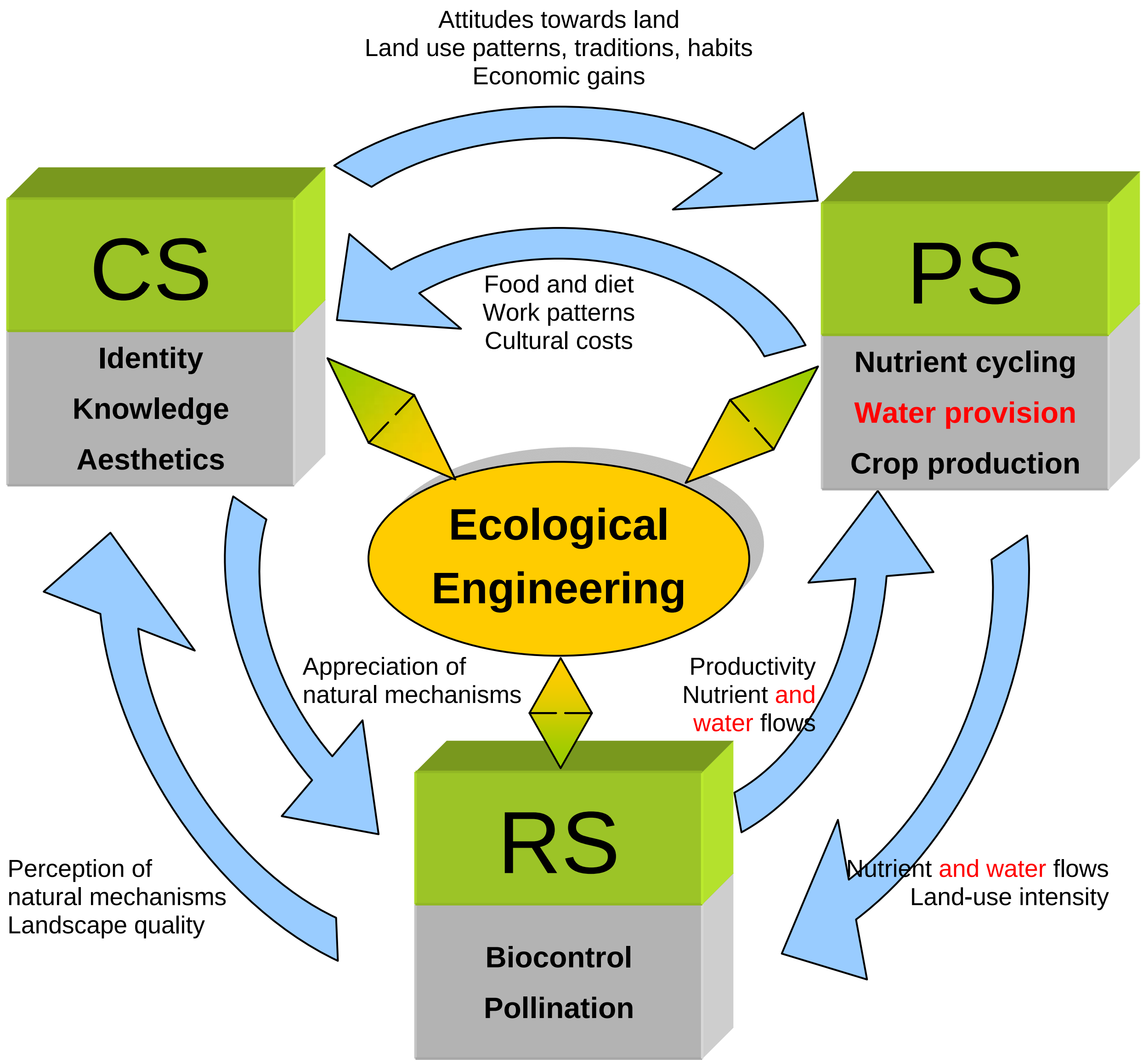


Figure 5.2: Relationship between different strands of Ecosystem Services and Ecological Engineering. CS: Cultural Services, PS: Provisioning Services, RS: Regulating Services.

LEGATO will test and improve already existing indicators for ESF/ESS and their values - building upon but going beyond existing indicators sets. Specific integrative indicators for each of the three strands will be tested for their suitability, e.g., the "Human Appropriation of Net Primary Productivity – HANPP" (PS strand); the diversity of indicator plants (incl. weeds), pollinators, and natural enemies of crop pests (RS); and the diversity of charismatic species of conservation concern such as damsel- or dragonflies (CS). Indicator research will be done on intra-, trans- and superregional scales via cross continental comparisons. The DPSIR scheme popularised by the EEA (see Figure 5.3) illustrates the forces affecting the provision of services (different levels of driving forces like population dynamics or climate change, and pressures like migration or land use intensity changes), and the levels where they can be observed (state, for instance loss of familiarity with agricultural practice, or changes of that practice by mechanisation and introduction of hybrid varieties, and impact, e.g. loss of identification or loss of traditional traits of agricultural practice).

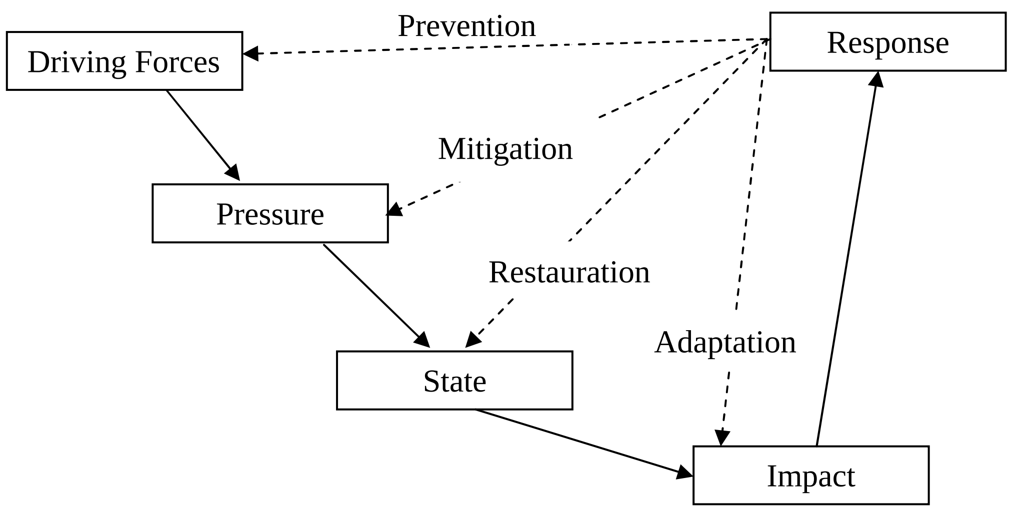


Figure 5.3: The DPSIR model

The indicated components of this system will be external constraints (e.g. dynamics of climate, technology, legislation, policy), external and internal driving forces (socio-cultural and economic factors, e.g. motivations of the actors and economic activities), the resulting pressures on the environmental compartments (e.g. agriculture related environmental inputs), and their consequences, the changes in ecosystem state, structure, function and integrity. These changes have impacts on environmental issues (ecosystem services) and human well-being.

Straight lines: selected causal relations. Dotted lines: different classes of responses

The diverse responses include prevention, mitigation, restoration and adaptation, dependent on the level of urgency, the objective of the measure resp. the level of institutional drivers it addresses. For instance, effective prevention of population pressures requires changes on the level of orientations (family values), and mitigation of climate change does the same (another ideology of progress), but also requires adaptation to unavoidable climate alterations. Ecological engineering challenges the prevailing idea of progress (tertiary driver), needs to be implemented in hands-on interventions in the landscape (primary drivers), at best supported by policies and governance (secondary drivers).

ANTHROPOSPHERE

***Tertiary Drivers*: Structures and processes of society incl. traditions, values, ideologies, habits, …**

***Institutions*: Orientations**

***Secondary drivers*: Processes in policies, governance, economy**

***Institutions*: Mechanisms**

***Primary drivers*: Interventions, causing biophysical disturbance**

***Institutions*: Organisations**

***Pressures*: anthropogenic, social and biophysical impacts on biodiversity**

***Ecosystem services*, structural impacts on the macro level**

***Bioprocesses*, process impacts on the micro level**

BIOSPHERE

Such a institutional drivers' hierarchy analysis as developed in the ALARM project will complement the DPSIR approach to illustrate the interaction of the economic and socio-cultural factors with geo-biogenic ones in shaping landscapes and ESS provision and recognition.

5.1.2 General State of the art: ESF (ecosystem function) and ESS (ecosystem services)

The agricultural landscape supports human life through the supply of crops but also of numerous other goods and services, material and immaterial ones. The Millennium Ecosystem Assessment (MEA) has provided a conceptual framework (MEA 2003), as well as a robust methodological basis (DeFries et al. 2005), for the quantitative linkage between the biological functioning of organisms and ecosystems in landscapes, and key aspects of human well-being. It has also provided comprehensive scenario assessments on the global, as well as on regional scales.

5.1.2.1 Provisioning ecosystem services in managed cultural landscapes

While the MEA has substantially advanced the concept of ecosystem services (pioneered by G. Daily, 1997, and others during the preceding decade), it still requires further development in order to serve as a suitable foundation for landscape management. The main objections raised in the recent literature concern the incomplete knowledge of ecosystem functional aspects in relation to service provision, the (apparent) failure to recognise “inherent” and “intrinsic” values of ecosystems (ethical and theory of science concerns, see e.g. Spash 2009) or, conversely, the (perceived) focus upon economic valuation based on current subjective preferences (Redford, Adams 2009). Furthermore, whereas, the interaction of cultural habits, social structures and economic dynamics has been analysed in agricultural and development studies, this body of socio-economic and anthropological literature does not relate their results to the concept of ecosystem services. It is also necessary to better respond to the claim that landscapes are more than a set of ecosystem functions and their services, but a higher system level with its own emerging properties (Trepl 1997).

At the same time, policy makers in the public as well as the private sector are beginning to use the ecosystem service concept widely, recognising the economic value of ecosystem services as a communication tool between themselves and scientists/experts involved in assessments of potential land management pathways, as illustrated by the TEEB (The Economics of Ecosystems and Biodiversity) project, funded by the German government and the European Commission. However, the simple assumption that preserving ecosystem services would *en passant* guarantee the conservation of biodiversity is giving way to a more differentiated picture, to which LEGATO will add new facets.

5.1.2.2 Provisioning services of natural ecosystems for stabilizing ESS

Natural ecosystems provide water, nutrients and habitats for pollinators or predators of consumers who would otherwise threaten crop productivity (Altieri 1999, Martins & Johnson 2009). In an ideal landscape structure, where agricultural fields are embedded into a matrix of natural ecosystems, insect outbreaks that endanger crop production can be reduced through stabilized food-web structures (Bianchi et al. 2006, Khan 2008). Likewise, nutrient loss through soil erosion or leaching from the fields is reduced, e.g. by the implementation of agricultural practises with low soil disturbance, which support a diverse and functioning soil microbial and faunal community, ensuring soil nutrient cycling (van der Heijden et al. 2008), soil stability (Rillig and Mummey 2006); and providing protection of plants against pathogens (Bardgett 2005, Maherali and Klironomos 2007). Such structures prevail in many traditional, subsistence oriented agro-forestry systems based on shared possession, but are increasingly converted into private property based intensive agricultural systems by social modernisation processes. Modelling studies or field investigations have concentrated on the role of biodiversity on the integrity of agro-ecosystems and maintenance of their functional diversity, mostly leaving out the socio-cultural dimension. Understanding the cultural background and the population’s attitudes and aspirations is essential for understanding the potential for change, but also the dynamic developments underlying seemingly inert economic and land use structures.

Intensive agriculture maximises a few services (mostly only one, agricultural yield) at the expense of all others, thus putting the provisioning of a wide range of ecosystem services at risk (WBGU 2009), while the integration of natural ecosystems into the mosaic of managed land stabilizes them (Zhang et al. 2007). The spatial arrangement of these land use types as well as the minimal size of the natural ecosystems required to provide these services depend on regional-specific conditions of climate, habitat requirements of key species that stabilize the respective food-web structure, and their regeneration potential (e.g. Tscharntke et al. 2007), while the spatial arrangement of current land use and the role natural areas play (something to be preserved or to be overcome) is determined by cultural and socio-economic factors. This naturally and anthropogenically generated functional diversity contributes to the stabilization of ecosystems and their provisioning services (MEA 2005). Managing the provisioning service this way is the result of a socio-cultural learning process which can be regarded as a part of and condition for the successful implementation of the ecological engineering strategy to enhance crop productivity as a result of higher landscape and functional diversity.

Future climate change conditions will affect regions differently, thereby changing natural and socio-economic conditions, in particular crop productivity and food demand, but also other physical (e.g. water availability and quality) and socio-economic factors (e.g. availability of plants with a special meaning, or the minimum size of agricultural area needed to feed a family) which are not part of the LEGATO analysis. All of these changes will impact production patterns and trade, contribute to further accelerated land use change, and thereby increase the pressure on natural ecosystems (IPCC 2007). Ecological engineering, as a management strategy integrating local knowledge and experience, is aimed at stabilising food-web structures and enhancing productivity by minimising pre-harvest losses. It has been identified as one possible strategy to mitigate losses from climate change. However, it is an open question whether the improvements achievable through ecological engineering – even if embedded in local cultures and thus fully exploited without any “hidden resistance” – will be sufficient to mitigate these land use and climate change effects, and which are the most appropriate ways to integrate ecological engineering into the prevailing socio-cultural conditions (not least to turn it from a potentially short term fashionable practice into a prevailing habitual attitude towards land management). Consequently, this will be a matter of further investigation within LEGATO.

5.1.2.3 Knowledge gaps and research needs

For the stated LEGATO purposes of improving sustainable land use management, much remains to be developed for the scientific foundation of ESS-based landscape analysis and its link to the prevailing socio-cultural and economic conditions. Even regarding the natural science knowledge base, there are significant gaps to be filled: Plant physiology and basic plant-animal interactions are known only to a certain degree, and there are therefore limits to the assessment of functioning of productive ecosystems in terms of basic provisioning services: species invasions, unprecedented CO_2-levels or socio-cultural innovations like the introduction of new management strategies can all cause no-analogue situations for which only limited knowledge exists.

Beyond these first-order limitations, additional problems need to be addressed. The definition of economically valuable services depends on culture-dependent subjective preferences which all vary over time, the social groups involved, the social structures in the region, global markets, or in relation to spiritual perceptions.

Socio-cultural services differ from the provisioning and regulating services as they are based on a more subjective definition of what is perceived as a service. For instance, the applicability of the category "aesthetics" to natural or anthropogenic systems or structures differs between different cultures. Thus the first step in the respective research processes is the identification of those socio-cultural services which are perceived as relevant by the stakeholders, embracing the landscape, its structure and use. Only then can those traits of (agricultural) systems be identified which constitute or contribute to socio-cultural services, both objectively (e.g. LEGATO strands 1 and 2) and subjectively (LEGATO strand 3).

5.1.3 State of the art in relation to the LEGATO core components

5.1.3.1 Nutrient cycling in rice

Nutrient cycles link agricultural systems to their societies and surroundings. Fertilizer inputs and use of agro chemicals are essential for high yields, but may impinge on the financial balance and shift the energy balance into negative territory. Leaching, downstream and downwind losses of these same nutrients and agro chemicals may diminish environmental and water quality as well as human well-being (Vitousek et al. 2009).

Agricultural nutrient balances differ substantially with economic development and land management practices, from inputs that are inadequate to maintain soil fertility to excessive and environmentally damaging surpluses in rapidly growing economies. Nutrient balances are also crop specific, strongly dependent on edaphic conditions and are expected to be altered by climate change as temperature and water availability drive transformation processes in soils (Cassman et al. 2003). Crop nutrient status is not only a key to high biomass production but through its interaction with biotic stresses (pathogens, pests) is a potentially important element of biocontrol and thus strategies of bioengineering (Throop & Lerdau, 2004) or ecological engineering. Nutrient management is an important feature in most traditional agricultural management systems.

Recent examples of extremely different nutrient cycles for corn growing systems were compiled in Vitousek et al. (2009), comparing China, Kenya and the USA. Based on these drastic differences between systems, LEGATO aims at such a system comparison for rice. However, the focus will be not just on N and P, but also on silicon (Si) as this element is of special relevance for grass species, rice in particular.

5.1.3.2 Biocontrol and pest dynamics in rice based systems

In agricultural landscapes, one of the services considered most at risk from agricultural intensification is biological pest control (Tscharntke et al. 2005). In rice, the most-produced cereal in the World (FAO 2007), insect pests, such as the brown planthopper, *Nilaparvata lugens* cause a massive loss in crop production each year, especially in Asia. Despite attempts for regulation and the use of Integrated Pest Management (IPM), the continued use of insecticides still results in significant side-effects on biodiversity and health issues in humans. Biocontrol by natural enemies such as predators, parasitoids and pathogens can significantly contribute to reducing the need of spraying insecticides. Because local biodiversity, agricultural practices and landscape factors influence the diversity and abundance of natural enemies (Tscharntke et al. 2005), sustainable agriculture requires a deeper understanding of the role of these factors for biocontrol. Further, Settle et al. (1996) demonstrated that there is a strong trophic linkage between organic matter, decomposers and generalist predators in irrigated rice fields and that a high intensity of natural biological control can be maintained by boosting the decomposer system via organic matter inputs. The increase of organic matter input accompanied by a decrease of insecticide application can be suggested as a promising approach for natural biocontrol in the framework of a sustainable land use.

5.1.3.3 Pollination with particular reference to biocontrol

Pollination by wild animals is a key ecosystem service, particularly in agricultural landscapes. Animal pollination is important to the sexual reproduction of many crops (Free 1993, Westerkamp & Gottsberger 2000) and the majority of wild plants (Kearns et al. 1998, Ashman et al. 2004). A recent review demonstrated that 87 of the leading global food crops for fruit, vegetable or seed production are dependent upon animal pollination, while only 28 crops do not rely upon animal pollination (Klein et al. 2007).

Over the last decade increasing concern has been raised about the declines and losses of pollinators and the deterioration of the ecosystem service they provide (Cunningham 2000, Donaldson et al. 2002, Committee on the Status of Pollinators in North America 2007). Land use changes resulting in habitat loss or alteration, agricultural intensification, and climate change are considered as main drivers of pollinator declines and losses (Millennium Ecosystem Assessment 2005, Tylianakis et al. 2008). In particular, tropical crops may be most susceptible to pollination failure from habitat loss (Ricketts et al. 2008). However, data over long time-spans that are documenting declines or losses are extremely scarce (Ghazoul 2005). Only recently, parallel declines in pollinators and insect-pollinated wild plants could be demonstrated (Biesmeijer et al. 2006). Moreover, there is still limited knowledge on the effects of climate warming on plant-pollinator mutualisms. Especially, demographic consequences of mismatches in pollination interactions are largely unknown (Hegland et al. 2009).

Some knowledge exists about scale-dependent effects of habitat fragmentation and land use intensification on pollinator abundance and diversity (e.g. Westphal et al. 2003, Kremen et al. 2004, 2007, Brosi et al. 2008). Yet, future studies are needed to build on the achieved knowledge and to reach a more general understanding of (1) the effects of landscape components and their arrangement at different spatial scales and (2) the importance of changes in biodiversity on pollinator communities and the ecosystem service they provide (Steffan-Dewenter & Westphal 2008). Because of their great importance for crop production and conservation of diverse plant communities, investigations of pollinator communities at landscape scale link agricultural systems, surrounding landscapes and the society. Hence, they are a suitable indicator linking land use activities with environmental and socio-economic conditions (WPs 4.2, 4.3).

Natural pest enemies are influenced by the complexity of the landscape surrounding crop fields. Structurally complex landscapes with high habitat connectivity and diversity may enhance the probability of pest regulation not only in temperate agricultural systems (Tscharntke et al. 2007) but also in tropical irrigated rice systems (Settle et al. 1996). Resources that are available in (semi-) natural habitats can sustain enemy populations and these enemies then spill over in crop fields and control pest organisms there (Rand et al. 2006). Increased habitat heterogeneity and plant diversity can provide natural enemies with resources such as alternative hosts or prey or plant based foods such as pollen, nectar, or honey dew (Landis et al. 2000). Particularly nectar-feeding parasitoids might benefit from flower-rich (semi-) natural habitats (Heimpel & Jervis 2005). Since the detection of parasitoids is often difficult, labour-intensive, and time-consuming, indicator taxa that are easier to detect would help to assess natural levels of biological control. Based on the indicated levels of biological control, effective ecological engineering and conservation measures can be developed and implemented. In congruence with nectar-feeding parasitoids, pollinators are also affected by landscape complexity and the availability of flower-rich habitats. Hence, pollinators might represent a valuable indicator for ecological engineering and potentially for biological control due to their scale-dependent and species-specific responses to landscape complexity and other driving factors of global change, such as climate (Schweiger et al. 2010).

Moreover, efficient and standardised sampling methods for pollinators are well known and applicable in different biogeographical regions (Westphal et al. 2008).

The assessment of pollinators (bees in particular) will hence serve two functions. One for assessing pollination services and two as an indicator for parasitoid richness, as these species are most important to natural biological control of brown plant-hoppers n rice. In conditions of high hymenopterans, egg parasitization of plant-hopper eggs can reach 100% compared to less than 10% in low hymenopteran situations. In Asia, most farmers don't perceive the concept or the existence of egg parasitization. As these species are tiny, it is also difficult to communicate the concept. Since bees are well recognized by farmers, they can be used as "relatives that will attack the plant-hopper eggs". A rice field with more bees which are observable will thus be less vulnerable making such a "target" an incentive to "feel safe". Some preliminary work done in China has shown that the ecological engineering fields have higher parasitoid biodiversity. The bee indicator can be used to facilitate communication, both in training programs as well in mass media and motivational campaigns. In China we also found that the use of bees as the entry point to discuss about egg parasitoids with policy makers had been effective.

5.1.3.4 Cultural identity & aesthetics in rice landscapes

The Millennium Ecosystem Assessment offers a global view of the importance of ecosystem services. However, to achieve an understanding of the relative significance of different ecosystem services in Europe and South-East Asia and the role played by cultural landscapes (e.g., annual crop based production systems) deeper investigations need to be undertaken, as foreseen through Strand 3 and its integration into the common indicator framework (WP 4.2) as well as into the integrative ecosystem functions/services assessment (WP 4.3) in LEGATO.

It is assumed in many instances that for farmers provisioning services rank highest, but their preferences are shaped by identities partly based on specific cultural values and traditions, but partly also on the external environmental and climatic situation as illustrated by the conflicts arising when capital intensive agroforestry systems replace subsistence and the economic calculus clashes with spiritually defined community-land relations (see e.g. Gerber 2010). Another example are climatic effects on cultural identity which can be very severe – being evident in the struggle for life on several Small Island States, for instance the Seychelles, with evacuation and migration plans for a whole state, or the identity problems of the inhabitants of Bikini and French Polynesia, where island populations were evacuated to conduct nuclear test explosions in the 1950s/60s.

Whereas in Europe the growing number of farmers opting for organic or other forms of low-input agriculture reflects market changes, but it is also one expression of the (cultural) value changes and the concerns regarding the sustainability of current agricultural practices, low input agriculture in Asia is not a post- but pre-intensification phenomenon. Here as well aesthetic values can play a role (regardless if shared by local communities): among other aspects they are the basis for rural tourism, an important source of additional income in many farming communities. Many non-rural citizens (and foreign tourists in particular) place a high value on the existence of healthy ecosystems with their flora and fauna, but also on the existence of diverse agricultural landscapes, and the opportunity to enjoy them. Although the impacts of tourism on rural communities' cultural identities (including but not limited to traditional values, the role of money, settlement and consumption patterns) are not necessarily positive, climate change can threaten livelihoods by undermining important sources of income like income from marketing their product or their region, the latter by reducing the perceived aesthetics of the landscape, the prevalence of familiar species, or by relocating tourist flows (e.g. by providing new and thus more interesting alternatives by making new regions accessible to tourism).

These risks are partly caused by the fact that cultural services are (a) subjective and thus due to rather rapid cultural change, including adaptation to a perceived mainstream culture, and (b) mostly associated with less-intensively managed areas, where semi-natural biotopes dominate. Low-input agricultural systems are also likely to support cultural services, with many local traditions based on the management of land and its associated resources (e.g., the celebration of Thanksgiving Day). There is evidence that people consider homogenous cultural landscapes with impoverished flora and fauna, as negatively affecting their recreational ability (EASAC 2009). However, whereas degraded natural and impoverished cultural system loose part of the value attributed to them, human activities, embedded in socio-cultural traditions and prevailing environmental conditions, do also create new aesthetic values, for instance in urban design or architecture. Landscape and architecture are both major elements of the visual impression and terms like "ecological aesthetics", "environmentally-friendly construction" and "climate conscious architecture" are being discussed. Also at the moment, looking at architecture we can see a great impact of the discussions on sustainability, energy efficiency and stability (as a response to earthquakes and floods) on current designs. However, the valuation of architecture is also value- and time dependent – see the disputes regarding the aesthetics of old and modern windmills.

Many cultural services, such as aesthetics and existence values, are non-use values where direct economic valuation is hard to apply. LEGATO will therefore combine social and economic valuation with indicator based reporting to be able to adequately address the field of cultural services. Here, a strong cooperation and interaction with the indicator working group (LEGATO WP 4.2) and the integration work package (WP 4.3) will take place.

5.1.3.5 Stakeholder participation in land use and ecosystem services

Stakeholder involvement or participation has been heralded as central element for modern environmental management (e.g. Meffe & Carroll 1994, Renn et al. 1995). However, neither the definition of “stakeholders” nor the meaning of “involvement/participation” is unambiguous. The concepts emerged in the 1960s’ as a means to move from central, technocratic rule to consultation and community management (Kemp et al. 2005). Stakeholder participation in decision making processes is now commonplace in EU policies (Meadowcroft et al. 2005), but far from self-explaining in many countries of South East Asia; in particular for the local population being herald in decisions affecting them is all too often the exemption rather than the rule.

Generally speaking, stakeholders are all those involved in and/or affected by a certain measure, so the act itself determines who is counted as a stakeholder, and the kind of involvement depends on the context (politics, administration, research, see e.g. Spangenberg 2003). In LEGATO, the forms of involvement vary with the social science research methods and the dissemination strategies applied and are mentioned with the method resp. strategy description, whereas the term “stakeholders” is used throughout the application, but referring to different groups of individuals depending on the respective context.

It is supposed to ensure a balanced and holistic decision-making, inclusion of local knowledge and a flexible implementation through shared ownership of decisions and thus higher levels of dedication to implement the outcomes (Stoll-Kleemann & Welp 2006).

Following the participatory approach, various sectors can be integrated, such as regional planning, economy (including tourism), nature conservation, and agriculture. Considering participatory processes, three levels of participatory methods can be distinguished from one-way communication (informing) to two-way communication (collecting or exchanging information) to mutual communication (joint planning and solving conflicts) (see Pretty 1995). Useful tools to support this communication are indicators. Therefore and in order to develop indicator sets which are understandable for local people as well as applicable for scientists, the indicator derivation in WP 4.2 will take place as an iterative process, involving local people as well as scientists from the different disciplines in LEGATO.

Possible methods and tools to examine participatory processes are illustrated in Table 5.1.

These methods will be applied in LEGATO on a case by case basis to characterise stakeholders’ roles in ESF management and ESS provision, harvesting and consumption in agriculturally managed systems. Stakeholders are thus being made aware of their respective roles in and the measures they can take to improve ESF management. This process will take place building on the expertise available within the GLUES consortium, in order to promote a lasting positive effect on policy.

Table 5.1: Examples of possible methods and tools to examining participatory processes

Method	**What for?**	**How?**	**Sample size**	**Type of results**
Data collection methods, e.g. expert elicitation, back casting approach (tolerable windows)	Identify and discuss values and perception, tease out expert/local knowledge	Surveys: Questionnaires, interviews (individuals) Participatory Appraisal Methods (groups) Prioritisation / Visualisation techniques (groups)	Small	Qualitative to semi-quantitative
Data analysis: e.g. Multi-criteria analysis, Bayesian networks,	Frame problem, represent divergences, explore inconsistencies in views, find consensus, develop model of social/organisational learning		Large	Semi – quantitative to quantitative results

The stakeholder situation in the Asian experimental site offers a diverse spectrum of situations. The chosen transects offer gradients of different stakeholder influences and types of participation, from semi-urban lowland regions to rather remote highlands in Vietnam as well as in the Philippines. These gradients can be found within each transect (including varying with land use patterns from intensive to traditional agriculture, from large to small scale, etc.). Another gradient is expected to result from the comparison of socially, geographically and economically similar sites in the different countries involved (party state in transition, authoritarian democracy, dictatorship-turned liberal democracy) which still exhibit significantly different political cultures and administrative regimes. Finally, despite historic many commonalities and comparable social structures, diverse traditions and cultures prevail in and between countries (ethnic minorities are part of the field site populations).

The participatory process employed by LEGATO will vary between countries and sites as they have to be embedded into the local cultures as well as into partly existing participatory structures. The set of techniques will draw from participatory rural appraisal methods (PRA). Originating in applied anthropology it was initially developed for agro-ecosystem analyses in the late 1970s and first spread out in South-East Asia (Kumar 2006). PRA is described as a growing family of approaches and methods to enable local people to share, enhance and analyse their knowledge of life and conditions, to plan, act, monitor and evaluate (Chambers 1997). Developed and advanced by numerous practitioners in the field the methods are classified as space, time, and relation methods including maps, transects, seasonal calendars and trends, flow diagrams, and Venn diagrams. The major contribution of PRA has been the thrust on visuals and diagrams, which enable even the non-literate and less articulate ones to participate meaningfully in depicting their situation and coming up with plans to change their situation. These detailed methods will be adapted to the local situations by experienced scientists from the respective countries, who have been selected for their track record of participatory research with comparable population groups. For example good experience was already gained from case studies in Indonesia applying resource mapping (see Fig. 5.4). A resource map in PRA is not drawn on scale and the local people are considered to have an in-depth knowledge of the surroundings where they have survived for a long time. A resource map reflects how people view their own locality in terms of natural resources. However, the process on the ground will necessarily require social learning from both, scientists and stakeholders.

Figure 5.4: Resource mapping with a group of farmers in the area of Lore Lindu National Park, Sulawesi, Indonesia.

5.1.3.6 Experiments and ecosystem services – natural science

Land use changes (regardless of their respective causes and the driving forces behind) lead to shifts in the distribution and diversity of organisms providing important ecological functions, particularly pollinators, decomposers and natural biocontrol agents (predators, parasitoids). These groups interact with plants and their associated herbivores (e.g. pest species) in multiple ways and shape the functioning of terrestrial ecosystems with consequences for agricultural land use (Brussard et al. 2007). Thus, the loss of biodiversity due to land use intensity is not only a socially constructed conservation issue but also threatens key ecosystem processes and functions with potential negative feedbacks on both long-term species survival and ecosystem services provided to human societies (Chapin et al. 1997); the demand for such services is part of the social science component in LEGATO. The relationship between biodiversity and ecosystem functioning and processes is a much debated and studied topic in ecology. Especially relevant processes are hydrology, nutrient cycling, primary productivity and biotic interactions (Hooper et al. 2005). There is an increasing recognition of soil biotic interactions as a crucial factor driving ecosystem services (De Deyn & van der Putten 2005). Nevertheless, and despite the ecological and economic implications, the relationship between biodiversity and ecosystem functions and the anthropogenic influence via land use on this relationship is only poorly investigated until now for the soil system (Antoninka et al. 2009).

The process of decomposition and release of nutrients in plant-available form is an essential process in the functioning of all ecosystems and controlled by climate, soil conditions and litter quality. The decomposer community is therefore of fundamental importance for the functioning of ecosystems, but has also shown to be strongly affected by land use and other environmental impacts (Bardgett 2005). Beside the rather obvious effects of decomposers on plant nutrition, site productivity and nutrient cycling, recent studies demonstrate a strong influence of this biotic process in the soil on the interactions between plants and the herbivores feeding on them (De Deyn & van der Putten 2005). Further, there is accumulating evidence that the decomposer fauna strongly contributes to the stability of populations of invertebrate predators with indirect effects of the control of plant-feeding insects by this group with implications for the biocontrol of pest species (Settle et al. 1996, Oelbermann & Scheu 2009, von Berg et al. 2009). Different traditional land use systems make use of this phenomenon and cultivate its effects, without any academic scientific basis.

The direct impact of land use change on biodiversity (including the destruction and conversion of natural habitats und the management intensification of agricultural ecosystems) is assumed to be even stronger than future effects of climate change, especially in tropical regions (Sala et al. 2000, Jetz et al. 2007). A high intensity of land use may significantly hamper climate change-induced dispersal and migration processes thereby slowing down the speed of adaptation to new climatic conditions and increasing local extinction risks (Warrren et al. 2001, Thomas et al. 2004). In this respect, traditional agricultural habits and use patterns may be superior to modern, high yielding management systems, exhibiting a higher resilience and adaptation capability. The indicator set from WP 4.2 will be used in collaboration with the integrative assessment work package 4.3 to carry out respective assessments of these different land use patterns, their environmental and socio-economic impacts (according to the DPSIR framework, see description of WP 4.2).

To conclude, an understanding of the spatial organization of key groups or organisms driving ecosystem functions, their dependency on anthropogenic land use changes and the consequences of the disruption of trophic interactions by biodiversity loss and climate change is of crucial importance for the implementation of sustainable land-use decisions. Traditional management systems, for all their resilience, developed over centuries, might easily be overburdened with the requirement to deal with the rapid changes of the physical and social environment. In this context, the assessment of patterns and relationships with land use intensity has to be complemented with experimental manipulations to unravel correlative patterns from functional mechanisms and to develop an understanding of which species provide key services and how they are affected by land use changes.

5.1.3.7 Experiments and ecosystem services – social science

In LEGATO, cultural services are “the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences”. Social experiments most often build upon well-documented status quo analyses and take the form of mental models allowing to answer “what – if” questions regarding potential future behaviour of the stakeholders. Only rarely it is possible to induce observable behavioural changes and monitor them (at best quantitatively).

In South-East Asia good experiences have been made with two approaches, namely farmer participatory research and a participatory exercise to motivate change in cognition and decisions. Farmer participatory research (FPR) approach involves motivating farmers to engage in experiments in their own fields so that they can learn and adopt new technologies (Bunch 1989). This step, sometimes known as innovation evaluation (Rogers 1995) is essential for communication as well as for initiating diffusion. The main advantage of this approach is that farmers “learn by doing” and decision rules are modified on the basis of direct experience. To shape learning, interpretations of experience must provide information about what happened, why it happened and whether what happened was satisfactory or unsatisfactory.

Socio-cultural experiments thus include confronting stakeholders with different scenarios including changes in the natural (climate) and institutional conditions (policy, in Europe CAP) and test their stated or realised reactions to them, while socio-economic experiments address the material benefits people obtain in a similar fashion.

As all kinds of services, provisioning, regulation and cultural, are based on the same landscape, its inherent biodiversity and the human management of both, these services are not independent. For instance, economic valuation is focussed on monetising part of the provisioning services, while more recent experiments with PES (Payments for Ecosystem Services) focus on the regulating ones.

Cultural services draw on the same landscape, its functions and traits, but so through a culture specific interpretation. Thus the analysis of cultural services needs to explore the cultural framing of landscape experiences – a task for which the knowledge of provisioning and regulating services is of high importance. On the other hand, as those services are affected by the kind of land use and its intensity (a socio-cultural and economic variable), understanding the cultural services and their development dynamics will be essential for drawing conclusions regarding human behaviour and future land use patterns under different scenarios. This aspect will be analysed by another set of socio-cultural experiments and respective indicators, designed to explore the awareness of, familiarity with, and sensitivity for the biodiversity and its environment, the landscape. These experiments will use audio-visual tools to confront residents with selected elements of biodiversity and landscapes and evaluate their cognitive and emotional reaction. This provides information on the socio-cultural framing and perception of landscape traits, biodiversity and a number of ESS.

The participatory research will be complemented empirically by two other social experiments (provided the quality of reference data is sufficient), one being time budget analysis, comparing the stakeholders' trends with the national statistical data. The other one will be to qualitatively analyse and compare identities of local farmers with those of relatives who have left the country-side and moved to the city, temporarily or permanently. Interestingly, media reports from the Philippines seem to indicate that identification with the rural landscape and inherited traditions seems to increase with higher levels of education.

5.1.4 From the LEGATO strands via Modelling to Ecological Engineering

Taking the state of the art as a starting point LEGATO will elaborate research work along the three strands and head for increasing integration in the course of the project. Modelling will be one core methodology to achieve integration and together with the detailed and sectoral natural and social science research results deliver main insights for an implementation of Ecological Engineering which is adapted to the local situation, its biophysical and its socio-cultural (including economic) characteristics. All data that are generated during LEGATO (from interviews, measurements, modelling, scenario analyses) will find entry into the common indicator framework which forms the basis for the integrative interdisciplinary assessment. A common data base will be created, including social, economic and ecological information from the different research sites. This data base will be organized according to the ecosystem service concept and all data will be linked to particular services with appropriate accounting units (e.g. value systems on relative scales, production units, energy, monetary terms).

5.1.4.1 Strand 1: Provisioning Services (PS)

ESF: Primary production/nutrient cycling

=> ESS: Crop Production/Prevention of Nutrient Loss;

Agricultural ecosystems are based on primary production and nutrient cycling as core ESF. Their ability to provide important ESS, particularly crop yields, is dependent on the nutritional status of any patch as well as the vicinity and landscape setting of crop fields, and the management systems in place (including external nutrient cycles or replenishing activities). Nevertheless, soil-borne nutrients are an essential prerequisite of plant growth and an important indicator for soil fertility and therefore also for ESF and ESS of soils. Stability of nutrient supply may serve as a measure of resilience. Natural ecosystems are characterized by a nearly closed nutrient cycle, i.e. with limited atmospheric inputs via deposition and biological nitrogen fixation, and some losses due to leaching. Agricultural systems in contrast are characterized by a large export of nutrients via crop (sometime including straw) harvest. With increasing intensity, intended to increase crop production, large quantities of fertilizer inputs are necessary, which require an optimised management system (type of fertilizer, application technique, timing, cultivation practise) (Vitousek et al. 2009). Mismanagement may result in over-fertilization and often leads to eutrophication of terrestrial and aquatic ecosystems and to imbalanced nutrition (N, Si) which feeds back to decreasing resistance to biotic stress (Ju et al. 2009). The natural heterogeneity of soil makes fertilization difficult and a process understanding taking this variability into account is required for optimised management of nutrients in agriculture systems (this may partly be different with rice paddy soils which are to a large degree of anthropogenic origin and – at least in each patch and the top soil level – rather homogenous). Optimised management is also required to maintain variability in nutrient availability in adjacent sites which is important for the different levels of biodiversity in natural ecosystems (Cassman et al. 2003). Climate change, in particular increasing temperatures and/or torrential rain events may alter the transformation of nutrients and nutrient flows. Increased release of N through mineralisation and leaching of nitrate to the groundwater is predicted in some scenarios. The project will contribute to a better understanding of the natural fertility of soils, fertilizer use adapted to local situations, management systems and water budget under changing climatic conditions, and the relation between soil variability and biodiversity.

Modern cereal-based food production systems like rice are quite often monocultures which lower the potential for pest control and are limited in certain elements, in particular silicon (Si). Thus, continuous cereal cropping induces changes in cycling of this particular element: rice is a Si-accumulator plant with up to 6% Si in the dry matter (Marschner 1995).

Si uptake of a rice crop amounts to 400 kg ha^{-1} and is thus in the range of nitrogen (N) up-take. Weathering of Si containing minerals and Si solubility depends on temperature and is strongly affected by redox cycling, which is common for many paddy soils. Si fertilisation has been shown to promote growth of rice and to increase yield stability (Dobermann & Fairhurst 2000). In addition Si has been used as an indicator for water transport through plant tissue as it is accumulated in strongly transpiring plant parts (Epstein 1999). Si as well as N are not only the major constituents of plant dry matter apart from carbon, but it has been frequently reported that the nutritional status of both elements in plants has an impact on pest outbreak (Epstein 1999, Throop & Lerdau 2004). High Si concentrations decrease palatability of plant tissue and decrease the attack by plant sucking insects and by fungi, while high N concentra-tions have the opposite effect.

Despite its potential importance for cereal production systems Si is an understudied element in plants (Epstein, 1999, Ma et al. 2006) as well as in soil (Sommer et al. 2006). Nitrogen on the other hand is well studied, but is the major element related to productivity and eutrophica-tion (Cassman et al. 2002). Both elements potentially are of high relevance for biocontrol and their transformation in soil is temperature dependent and may be susceptible to climate change. Hence, within the framework of LEGATO the nutrient related topics will focus on these two elements which will provide crucial data and information for the overall indicator system and the ecosystem service assessment.

5.1.4.2 Strand 2: Regulating Services (RS)

ESF: Biodiversity/food-web structure/pollination

=> ESS: Biocontrol of Crop pests/Crop pollination;

Landscape management to increase the biodiversity of natural enemies of potential pests has a long tradition in Asia. It has the potential to not only increase biocontrol, but also to provide other services not covered by LEGATO (such as the contribution of fish and frogs from rice paddies to the diet). An assessment of this biodiversity helps to calculate current biocontrol potential and identify whether there is a need to increase this biodiversity.

This biocontrol potential may change in space and time, making it necessary to obtain infor-mation of food web structure. For example, the identity and abundance of cereal aphid an-tagonists greatly differs among regions and years (Thies et al. 2005). Unfortunately, an as-sessment of the biocontrol potential is often hampered by the difficulties in quantifying natural enemy abundances and food web structure. Hymenopteran and Dipteran parasitoids, main antagonists of insect pests in rice can often only be identified by taxonomists or people especially trained in insect identification, rendering biocontrol potential studies expensive and lengthy. In addition, assessments of natural enemy food web structure in the crop are time-consuming, as natural enemies often need to be reared from attacked insect pests. For example, eggs of parasitized rice leaf- and planthoppers need to be collected in the field to the assess food web structures.

Besides these technical-scientific aspects, the suitability of a certain species as a biocontrol agent is also dependent on the socio-cultural conditions: Does it need to be nurtured or is it self-sustaining? In the former case, can this be integrated into existing working patterns? Is there cultural resistance against the respective biocontrol species, and if so, why (often for a good reason)? Which impacts on work and management habits are to be expected? Is there past experience with biocontrol agents, and if so, can it be made available and useful for the bioscience research?

In contrast to natural enemies, pollinators are easier to catch and identify when visiting flowering plants. As an indicator system, the use of pollinator biodiversity to assess general food web structure would be highly preferable to direct estimates of natural enemy diversity, yet the relationship between pollinator diversity and overall food web structure is not clear.

LEGATO will contribute to a better understanding of the effects of land use changes, climate change and changes in biodiversity on two essential regulating ecosystem services: biocontrol of crop pests and crop pollination. If land use changes have parallel effects on both ecosystem services, an indicator framework based on pollinators will be developed to predict shifts in the biocontrol potential, for instance changes in the diversity of biocontrol organisms and/or changes in the food web structure of natural enemies of potential pests. As most of the regulating services are very difficult to account for in an appropriate way, the approach in LEGATO, focussing on species with quantifiable service provision, is a promising attempt and will provide useful information and date for the common indicator data base (4.2) and the integrative assessment (4.3).

5.1.4.3 Strand 3: Cultural Services (CS)

ESF: Landscape morphology/species pool

=> ESS: Cultural Identity & Aesthetics

Cultural services are “the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences” (WRI 2003: 58) - however, although the services as such are nonmaterial, they may generate material revenues from third parties. Human cultures and social interactions have always been influenced and shaped by the nature of ecosystems. Simultaneously, humankind has influenced and shaped its environment to enhance the availability of certain valued services.

Appreciating the high interaction between the natural and socio-cultural system, we have to overcome the nature-culture dichotomy separating both from each other in much of the current research. Landscapes not only have bio-physical attributes, they are subjected to and influenced by cultural perception as well.

In focus of the socio-cultural perspective is the human being in its social and psychological context, its material and non-materialistic needs, and the rational as well as the emotional components of its attitudes towards nature and society. In general, people across cultures and regions express aesthetic preferences for different natural or cultural landscapes and often attach spiritual and/or religious values to the regenerative aspects. In Asia, in particular, rice has richly shaped the cultures, lifestyles and consumption patterns of billions of people. For thousands of years, it dominates customs, beliefs, rituals, and celebrations. Religious rituals and cultural identity are thus linked to the rice cycle (Groenfeldt 2006).

The conversion of traditional cultural landscapes to modern, large-scale agricultural production units, and the degradation of natural ecosystems can diminish these benefits of identification with the locality and community spirit (direct and partly reciprocal social relations replaced by indirect, market and money mediated utility maximising ones), relative security as result of age-long tested management patterns, providing national symbols and being an inspiration for arts and folklore, dance, and fashion (MEA 2005). The loss of particular ecosystem attributes (sacred species/forests) and management options (e.g. shifting agriculture, forest grazing) can result in losing the local identity and the economic basis for survival. On the other hand, in some cases (such as where ecosystem attributes cause threats to the people) the loss of those attributes might enhance the people's local identity to what remains (MEA 2005). These human habits are closely interacting with landscape structures, creating semi-natural, sometimes diverse landscapes, and with the ecosystem services (using landscape for education and for leisure, at the same time providing income for farmers) – which in turn affect the way of land use management and the development of the future landscapes.

Thus many functions and services, even if not directly determining the survival or reproduction of ecological systems and human communities, make landscapes a very important source of wellbeing, directly affecting the quality of human life and the social structures in which it is organised. In addition to the basic physiological needs (clean air, water) human life requires many other needs to be fulfilled, both at the personal (aesthetic aspects, recreation) and at the collective (norms and values, local identity) level (Chiesura 2003).

Typical landscapes are known to be a key part of human identities and a precondition for sustained well-being, for a number of reasons. Nonetheless scientific investigations of what makes a sustainable landscape are in their infancy, and so far focussed on "pristine" landscapes. With the exception of recreational benefits from tourism, important insights into social and nonmaterial functions of nature are lacking (and thus also into the economic potential inherent to these services).

Traditionally, the term landscape referred to the beauty of the surrounding nature as a whole. Today, landscapes are shaped by humans, their management is more and more standardised (Haber 2001), and in the scientific analysis they are often reduced to a set of ecosystem functions (Trepl 1997). However, the perception of landscapes is not only determined by the changing land use patterns, but also by the evolution of intrinsic valuation criteria and categories the observer applies (Dinnebier 2004). Thus landscapes are a cultural product providing cultural services, e.g. they have an aesthetic quality, over and above their ecosystem functions and the provisioning and regulating services they generate.

Aesthetic values, identities, ecosystems and their services have one thing in common: they are artefacts, constructed entities, unlimited in number at least in principle; their definition depends on the attitude and interest of the external observer (a farmer, a painter, a scientist). In this respect they are clearly distinct from organisms and their communities, and from landscapes (Trepl & Voigt 2005).

Most of the recent research refers to cultural services in the context of natural landscapes to function as 'natural tranquilizer'. Little is known about aesthetic preferences and local identity of people in cultural landscapes (Gee & Burkhard 2010), such as the relation to land-use intensity and annual crop based systems (such as cereal production). The loss of these functions also would have critical economic impacts, which are all too often not taken into consideration. Besides provisioning and regulating services these aspects will be in focus of the LEGATO project.

Cultural services are less specific to determine and harder to evaluate than the provisioning and regulating services delivered through ecosystem processes (Piechocki 2005). However, a set of techniques (qualitative and quantitative valuation and preference methods) has been used to estimate non-market values of environmental goods (Chiesura 2003). Useful techniques in determining people's perception, attitude, and the unconscious components underlying their interpretation of nature, are participatory approaches and survey techniques with space for narratives and open questions (see also Rodriguez et al. 2006). The data of these investigations will be translated into indicator values to be integrated into the common indicator framework (WP 4.2). Moreover, they will be translated into the language of ecosystem services in order to be included in the integrative ecosystem service and scientific trade-off assessments (WP 4.3).

Using such methods, LEGATO will contribute to the understanding of landscapes as a key part of human identities and a precondition for sustained well-being. It will do so by linking the existing landscapes and their biodiversity to the analysis of ecosystem services, in particular to economics (PS), aesthetics and identity (CS) shaped by social and psychological processes. Thus the project will contribute to the understanding of the cultural value of anthropogenic imprinted landscapes such as those dominated by cereal production.

5.1.4.4 Ecosystem modelling und HANPP

At the global scale, humans appropriate about a quarter of the terrestrial net primary production, through either direct use or else destruction of plant and animal material (Haberl et al. 2007). This quantity, termed „HANPP“, has also been usefully estimated for regional and national case studies (e.g., Gingrich et al. 2007, O’Neill et al. 2007) and has become a useful indicator for human use of the ecosystem as well as for the effect human use has on the total resource base. As different methods have been developed to calculate HANPP, and as the results of different studies diverge, due to this methodological reasons rather than to changes in the underlying data (Haberl 2007), we have chosen the approach of Haberl to generate data with a high level of international comparability.

HANPP is a highly aggregated indicator as far as the ecosystem processes it refers to are concerned, but can be applied to the analysis of local conditions as well. It directly illustrates the extraction of energy resources that could otherwise be used in natural food-web structures and thus – according to the species-energy hypothesis (Gaston 2000) – contributes to biodiversity loss (Haberl 1997, Wright 1990). This HANPP – biodiversity hypothesis has been empirically supported by the findings of Haberl et al (2004; 2005); however, as these results origin from Europe, a test in Southeast Asia will be suitable to validate or refute the hypothesis as a more generally applicable one. LEGATO will allow testing and further substantiating the hypothesis that HANPP can serve as an indicator for overall biodiversity trends.

Earlier studies applying HANPP in Asian rice agriculture ecosystems on the village level have shown its applicability to small scale agriculture (in a study in Thailand plots of 600 x 600 m were analysed, see Haberl 2002); there HANPP values of 70 to 80% (aboveground biomass) were found. Thus the agricultural, partly subsistence based rice cultivating community was found to live close to its ecological limits. This case plus similar findings elsewhere led to the hypothesis that agricultural societies tend to reduce the overall NPP on their territory, while simultaneous maximising the share utilised by society. However, whereas this may tend to hold true on larger scales, it is not necessarily so for the smaller scale. Whereas – as a rule of thumb – it is assumed that generally the NPP of the potential natural vegetation can be considered as an upper limit for production capacity of agrarian ecosystems, the terrace agriculture may offer one of the (so far more hypothetical) exemptions from that rule, as a case where (again hypothetically) the NPP of the prevailing agricultural systems exceeds that of the natural vegetation. According to the same hypothesis, for lowland rice production, the opposite is expected to be the case. Thus (in case the test of the method validates its use) a comparison of different rice agricultural systems, validated by a cross-country comparison of similar types, will provide valuable information regarding the influence of management systems and technology impact in rice agriculture on HANPP and thus on ecosystem processes and biodiversity.

HANPP also points out the amount of energy that ecosystems provide for human society, and therefore allows the direct quantification of some provisioning services (Haberl 2002; 2007). HANPP is calculated by determining the amount of carbon or energy lost due to from land cover changes (NPP of potential natural vegetation minus the one of current land use), and the current extraction of carbon or energy by cropping, grazing and forestry. Difficulties from allocating HANPP to multi-annual vegetation and to animal grazing are limited in the sites analysed by the project; data availability and statistical incoherencies – otherwise a major problem – will be limited as most data are collected (spatially explicit) and the relevant ecosystem models are developed resp. Adapted to the local conditions (see below) in the course of the project (using regional-specific inventories even NPP appropriated in human-caused fires can be quantified, Haberl et al. 2007). The methods in managing cropland or maintaining cropland productivity and evaluating them in terms of their ability to allow a sustainable appropriation of NPP that ensures the maintenance of ESF and ESS is about to come into focus on respective research agendas.

The regions where biomass is produced (where HANPP is calculated and where ESS are generated) and where it is being consumed (the usual location of the impacts of consumption) are spatially disconnected, which also changes regional carbon balances as well as exploitation of natural resources. This can also have an impact on ESF and ESS of the producing croplands (Erb et al. 2009). The spatial disconnection of ESS provision and consumption poses severe allocation problems in particular when defining mitigation strategies; LEGATO will have to develop exemplary solutions to this dilemma for the ESS analysed.

One way to assess HANPP, and develop scenarios for it, is through the combination of inventories and modelling, e.g. the generic ecosystem model LPJmL (Sitch et al. 2003, Bondeau et al .2007), which simulates NPP, carbon allocation and vegetation dynamics for natural vegetation, and NPP, growth and harvest for crop functional types. However, validating the model for a specific regional context usually involves field site analysis as described above. Through incorporation of future climate and land use change scenarios into the LPJmL model, and the data underpinning the alternatives (including changes in social and economic patterns) from the field research, the relationship of how much the climate would allow the human society to appropriate from their croplands can be investigated. Additionally, it is possible to analyse the impact of global and regional land use change on carbon storage and fluxes.

We intend to test the method by evaluating the impact of ecological engineering on HANPP, for the study regions of LEGATO, through direct quantification of respective NPP in natural and cropland vegetation under different climate and land use conditions. If HANPP turns out to be a sufficiently sensitive indicator to reflect the changes caused by the transition towards ecological engineering, the project will use it to analyse and document the trends in ecosystem and biodiversity effects invoked by such a transition.

5.1.4.5 Ecological engineering as a means for ecosystem service application

Ecological engineering is the development of strategies to maximise ecosystem services through exploiting natural regulation mechanisms instead of suppressing them. Modern agricultural systems are often designed to maximise specific provisioning services at the expense of other services and are characterized by low biodiversity, whereas in traditional systems multifunctionality and a higher level of biodiversity prevail. In addition, ecosystem services such as invasion resistance and pest regulation are further depressed by pesticides, as opposed to regulation by natural enemies. In rice production, insecticides sprayed especially in the early crop stages of many, particularly high yielding rice cultures cause disruptions that can lead to outbreaks of pests such as planthoppers. Some pesticides such as imidacloprid are also detrimental to pollinators. As opposed to this approach, ecological engineering works the opposite way. It enhances biodiversity e.g. by providing refugia, food and breeding places for predators, parasitoids and pollinators to keep damage by pest to a minimum level while fostering the delivery of a wide range of ecosystem services. In a certain sense it is an attempt to introduce time-valued principles of traditional agriculture into the context of more modern, higher yielding agricultural management practices. The approach chosen in LEGATO, with three classes of services analysed, will permit to assess the effectiveness of ecological engineering and its suitability under different socio-cultural conditions on a broader scale.

The effectiveness of this approach has been empirically demonstrated: Research in Europe, Australia and New Zealand has shown that biological control can be enhanced when habitat biodiversity is increased through the introduction of different crops or other non-crop vegetation. In China, Vietnam and Thailand, where planthoppers are pest problems, ecological engineering strategies to strengthen invasion resistance have been successfully introduced; the results are now being evaluated.

Parasitoids seem to be closely related to pollinators in their abundance. But pollinators (especially bees) are more readily visible and have a positive image. This makes them suitable to more easily convey messages to the public and to policy makers. Thus, pollinators could serve as indicators of biocontrol and successful ecological engineering.

5.2 Applicants' own work to date

The applicants' own work to date comprises hundreds of scientific papers as well as practical collaborative work between industry, SMEs and extension services. The coordinator has a long standing experience in successful coordination of complex projects. We have summarized the experience and listed the most relevant publications of each group and all individual colleagues involved in LEGATO in Part Ib of the proposal, which was a separate document. As there has been much collaboration before, several papers have been co-authored between groups.

5.3 Economic importance

The value of ecosystem services, if defined as ecosystem functions people value as services (and recognise their origin in the ecosystems) can be assessed by a wide range of social science and in particular economic methods. Consequently, global estimates vary widely, from a few percent to three times the global GDP (see the seminal paper of Costanza et al. 1997). Understood in a broader context, their value can hardly be overestimated: from the world's biggest industry sector, tourism, and the rapidly growing share of ecotourism, to human capital formation (education) and mere physical existence (food, water and shelter provision) ecosystem functions, services and their resilience are indispensable for almost every aspect of human life and culture.

Even the monetary figures covering a mere fraction of the value to humans (in economic terms, the World GDP is an upper limit to market values) are impressive: Flood/fire regulation and climate regulation have the highest non-market economic value, comparable to the market value of recreation and tourism. Crops only rank second, although even minor contributions like those from agricultural seeds and organic agriculture amount to market values of about 30 billion € a year each (ten Brick 2009).

These contributions to human livelihood are, however, extremely different depending on affluence levels and cultural specifics. Their loss is most intensively felt on the local level and by poor people (mostly peasants), but often not in the contexts decisive for policy making. In particular, ESF and ESS are critical for the informal economy: agriculture, animal husbandry, and informal forestry constitute the "GDP of the poor" which is heavily affected by the loss of biodiversity and declining levels of ESF/ESS (Sukhdev 2008). Thus it is important to include the valuation "languages" of different social and ethnic groups in any economic analysis, when identifying socio-economic drivers of trends like modernisation of agriculture, and in making comparisons in and between countries. In particular in decision making processes where local communities are not heard, economic arguments tend to play a major role. One objective of LEGATO is to broaden this approach to the inclusion of a broader spectrum of socio-economic decision criteria by providing valuations (monetary and non-monetary) of ESF and ESS.

These functions and services are at risk due to increasing land area required for settlement, infrastructure (with growing population) and meat production (changing consumption patterns with growing income levels), and last but not least with climate change. The International Food Policy Research Institute IFPRI (2009) expects without climate change 2000 – 2050 about 4/10 increase of rice production in South Asia, but a rather stagnant one in the East Asia & Pacific region (for comparison: wheat production in Europe and Central Asia is expected to double). Under an A2 climate change scenario, the surplus in South Asia is expected to be reduced by 1/3, with East Asia & Pacific in 2050 could be suffering from about 1/10 yield losses compared to 2000, in absolute figures. Thus climate change has a double impact on human well-being: directly by changing precipitation, evapotranspiration and biological processes, and indirectly by changing the irrigation water supply reliability IWSR, and – as a results of declining yields and a possible adaptation strategy – altered land use patterns leading to impacts on prices, production and consumption, and trade. IFPRI expects the world rice price to increase by 6/10 already without climate change, and by twice as much under an A2 scenario (wheat prices are expected to increase by 4/10 without and by a factor of 3 under significant climate change (A2); global meat prices on average are expected to increase by 1/3).

Thus supply shortages would lead to significant price increases for grain and meat, enhancing malnutrition and disease susceptibility amongst the poor, again the most severely affected group, and undermining economic growth prospects. Successfully countering these trends in the conventional way of focussing on breeding high yielding varieties and increasing inputs would be expensive (about 7 billion US$ according to IFPRI) and is biologically hardly imaginable (increasing rice yields by a factor of 2.5 to 3 by further intensification as suggested by IFPRI stretches the limits what is physiologically possible).

Two avenues must hence be explored if development failure and increasing conflicts are to be avoided: increasing agricultural productivity (through applied agricultural research, rural infrastructure and irrigation, i.e. changing land use intensity), and reducing the pre- and post-harvest losses. The post-harvest side includes the need for infrastructures like effective rice driers (a major bottleneck in several South-East Asian countries, and possibly an emerging necessity in adaptation to climate change). Pre-harvest crop losses from infections and insect plagues also need to be systematically reduced. In LEGATO we will calculate the economic values of the provisioning service “crop production” and the economic risks emerging from infections and insect outbreaks (in terms of damage costs); nutrient cycling, biocontrol and pollination can be estimated as a fraction of the total production value. This can enable local community representatives to address higher level decision making processes in the language used at the decision table, and to specifically address the socio-economic drivers behind unsustainable trends.

One key element of ecological engineering is damage reduction through biocontrol, representing a paradigm change from considering losses as a challenge to plant breeding towards a task for ecosystem management. In economic terms, the working hypothesis is that a transition towards ecological engineering has negative avoidance costs, i.e. damage avoidance is coupled with reduced expenditures. If this hypothesis can be conformed in the field experiments, such a paradigm change would enhance the probability of avoiding major supply shortages by simultaneously increasing yields and reducing costs, thus providing opportunities for resilience-enhancing diversification. The communication of such policy decision relevant results is one key task of the coordination project; LEGATO will provide the analysis of drivers and obstacles (or sources of inertia) and pinpointed summaries of the research results in ecological engineering to GLUES, and will participate in the dissemination to bodies such as the CSD, FAO, WB, as well as to national governments and international governance bodies.

Complementing the monetary cost calculations (damage, repair and avoidance cost as applicable), the socio-cultural values of the agricultural landscapes (to be identified by the inhabitants, possibly including ethical, aesthetical and identity values) need to be analysed. Here values are rather understood as “relative importance to the beneficiaries”, and lexicographic rankings rather than quantification will be the adequate measurement method.

It is to be expected that there will be overlaps but no identity between the ecosystem services as defined in a scientific analysis and the perception of valuable services by local residents. One challenge of valuation will be to identify these overlaps, the possible links between the different fields of analysis, and use this information to assess future threats and potential damage cost resulting from changing land use intensities and climate change. The climate change scenarios, and their input on agricultural yields will be taken from the work of LEGATO partners, and from the coordination project.

The decision on which scenarios to use has a substantial impact on the results of LEGATO. LEGATO will strive by exchanging experiences with GLUES. This will yield meaningful results only if there is a measure of consistency between the scenarios used in either project. Hence, LEGATO will discuss with the GLUES how global scenarios can be downscaled to the study site in a consistent manner.

6. Scientific concept, work programme and methods

6.1 Scientific concept

As explained in chapter 5.1.1, LEGATO has chosen the analysis and evaluation of ESF/ESS, both in isolation and in concert, and their interaction with land use patterns in production systems of annual plants as the core issues to be considered. Thus the starting point of LEGATO is based on the MEA (see Fig. 5.1).

As it is however not possible to consider all of these elements we have chosen a subset of ecosystem functions and services which are a) particularly relevant for the cropping systems concerned, and b) for which indicators and respective data and can be quantified:

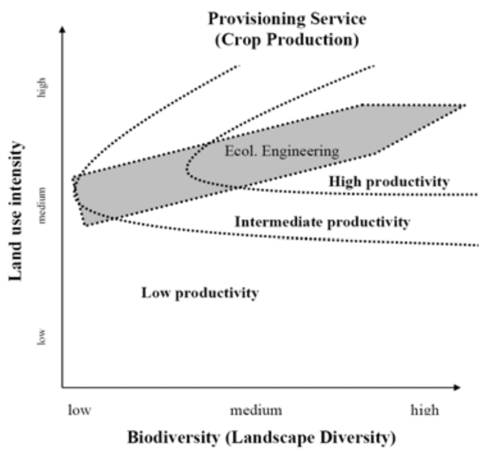
- **Strand 1 (PS**; Provisioning Services): ESF: Primary production/nutrient cycling
  => ESS: Crop Production/Prevention of Nutrient Loss, including consequences of/on water budget and quality;
- **Strand 2 (RS**; Regulating Services): ESF: Biodiv/food-web structure/pollination
  => ESS: Biocontrol of Crop pests/Crop pollination;
- **Strand 3 (CS**; Cultural Services): ESF: Landscape morphology/species pool
  => ESS: Cultural Identity & Aesthetics.

We interlink these strands with the most relevant pressures which impact upon them, which are 1) land use, 2) biodiversity, 3) climate, and 4) the social system in which they are imbedded – and with the changes of these pressures over time (i.e. the impacts of global change).

This will be based on input from and exchange with the relevant stakeholders and under different land use and climate change scenarios and their effects on environmental threats in the future. In order to get a systematic organization of all data and information to be acquired, the common indicator framework and the project data base have an outstanding integrating role. Thus, the indicator framework development will be one major collaborative action of the whole project consortium and the local stakeholders. The results are to be implemented again in close collaboration with relevant stakeholder groups. In particular we want to focus on Ecological Engineering under a set of hypotheses, two of which are graphically exemplified in Fig. 6.1, while Fig. 6.2 gives a graphical representation of the entire LEGATO approach.

6.2 Work programme

LEGATO will follow the work programme graphically lined out in Figure 6.3 (and Fig. 7.1). It will be structured into Workpackages (=WPs; for a more detailed graph see Fig. 7.1). Core elements of LEGATO are the feedback loops, particularly those in relation to the implementation of stakeholder recommendations (feedback WPs 1 with WP 2/3) and implementation of project results for practical outputs, like e.g. Ecological Engineering practices (feedback WP 5 with WPs 2/3 and 4).



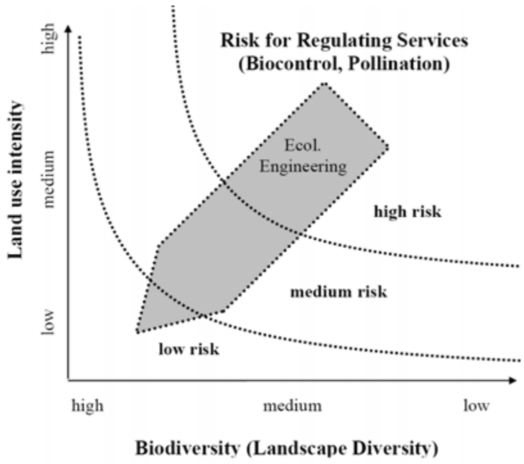


Figure 6.1: Hypothesized relationship of combined impacts of land use intensity and biodiversity on ecosystem services (crop production: left graph) and the risks for ecosystem services (biocontrol & pollination: right graph) with directions of ecological engineering policies aimed at improving the situation or mitigating the impacts.
In the left graph the increase of productivity through ecological engineering is hypothesized through a strong increase in biodiversity and landscape diversity combined with slight increase in land use intensity, while in the right graph the reduction of risks for regulating services through ecological engineering is hypothesized through both an increase in biodiversity and landscape diversity and a decrease in land use intensity. In which situations which of these hypothesized ecological engineering activities are to be implemented, depends on the local situation and context. These kinds of analyses are the core aim of LEGATO.

From the outset LEGATO will make use of the involvement of the broad spectrum of stakeholders and try to involve them throughout the duration of the project. Actually stakeholders are regarded as the major driving force for core research elements and modifications and substitutions in the course of the project in order to reach the necessary results for the implementation of LEGATO results. Thus, for approx. the first half of LEGATO we will maintain a multi-stakeholder analysis and consultation process (WP 1), which – for the second half of LEGATO – will gradually turn into the implementation process (WP 5); the latter again with the participation of the majority of stakeholders who have already been involved in (WP 1).
A more detailed account of the work programme is provided in chapter 7.1.

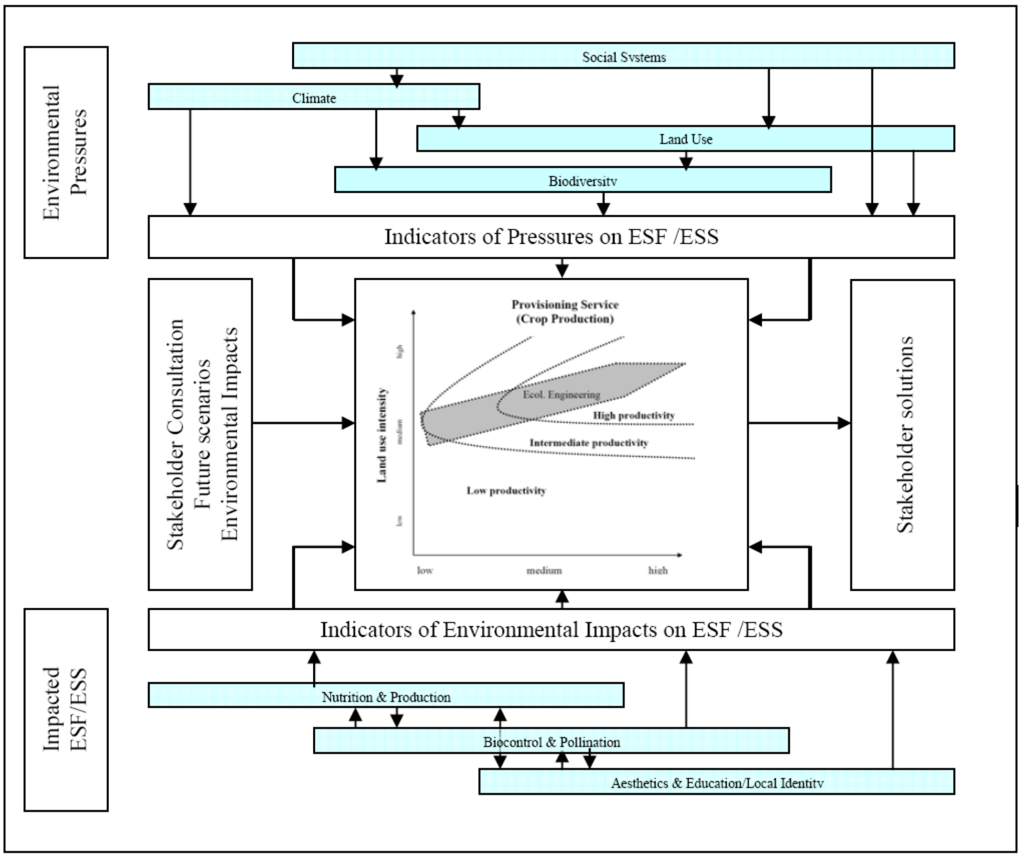


Figure 6.2: LEGATO research approach. LEGATO aims at a combined assessment of the indicators of pressures on ESF/ESS, which are the social system, climate, land use, and biodiversity (in a somewhat hierarchical and nested way) and the impacted ESF/ESS, which for the aims of LEGATO are Aesthetics, Biocontrol and Production. The assessments a) start with stakeholder consultation processes and selected future scenarios of environmental impacts, b) investigate the options for ecological engineering under particular local settings (i.e. stakeholder interests and local futures under different scenarios) and c) are disseminated to and implemented by the stakeholder communities.

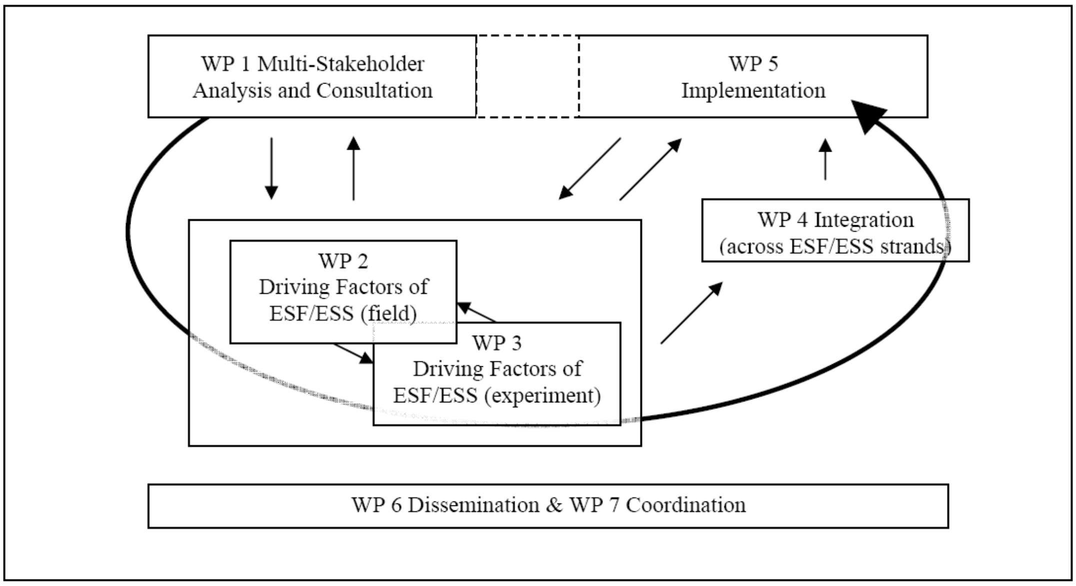


Figure 6.3: LEGATO overview structure and work flow

6.3 Research Sites and Methods

6.3.1 Research Sites

Overview

Studies are planned in South-East Asia (Philippines, Vietnam, Malaysia). The focus will be on irrigated rice and complementary crops like vegetables. Within pre-selected areas of investigation (AoI; see Table 6.1) sites will be selected with different land-use intensities and levels of structural diversity (also as surrogate for biodiversity; see Fig. 6.1). We hereby will distinguish between intensive (ITS; 4x4 km² in extend) and extensive, spot-like test sites (ETS). Assessments will be based on field data and inventories of existing system conditions complemented by literature studies.
These predominantly correlative studies will be supplemented by experimental sites for in depth-analysis of causalities.

Within the AoIs we will finalise the detailed selection of 4x4 km² ITS within WP 2.0. All ITS either follow a topographical and structural or cultural gradient or/and for direct comparison of comparable settings which only vary in a few frame conditions (like supposedly intensive systems in the Mekong Delta, the Red River Delta, the Muda scheme and Central Luzon). 40 ETS in each AoI are to be identified (20 only in the Mekong Delta), where simple standard assessments will be made, and which also will be conducted within the ITS to allow methodological comparisons and standardisation.

We expect structurally similar gradients of biophysical factors from mountain regions (Vietnam, Philippines) to the sea level (deltas); sites will be chosen to enhance international comparability. The number of AoIs and the choice of sites in collaboration with local administrations and consortium members provide the opportunity to choose local communities with partly similar, partly diverging socio-cultural characteristics. Diverging characteristics serve as the basis for comparative analysis, while similar characteristics are the basis for social experiments.

Justification for the selection of countries and sites

We propose three areas in Asia: Malaysia (Muda Irrigation Scheme), Vietnam (Tien Giang province in Mekong Delta and the Red River Valley from the Northwest mountain region to the delta) and The Philippines (Central Luzon from Banaue to Cabanatuan), along a climatic gradient and a gradient of rice cultivation extremes. The proposed investigation areas cover climatically the moist Tropics from equatorial (Malaysia) to the boundary of the Tropics (Vietnam) and to the cool Tropics (Banaue/Philippines). Sites will be selected in order to have in all areas sites with comparable parent material (young river sediments) and in addition a variety of sites developed from different parent materials, stage of soil formation and therefore distinct differences in nutrient fluxes by natural processes. Observations will be done in a parallel approach using different systems of farm management. In Malaysia rice in the Muda is intensive, fully irrigated, continuous rice-rice mono-cropping with low diversity in varieties. About 90% of the area is planted to 2 closely related varieties, MR219 and MR220. Chemical inputs are high, particularly pesticides making rice ecosystems vulnerable to pest outbreaks. On the other extreme are the Philippines, stretching from Banaue where rice grow on terraces to Munoz, where more intensive cultivation practices are carried. In between these two sites is Vietnam, where the Mekong transect cuts across rice and areas of fruits. Here rice cultivation is intensive with high inputs but the area is well diversified, mixing rice with fruits and numerous small patches of vegetable gardens; also the varietal mixture is more divers. The Red River transect includes rice terrace cultures in the mountain sites and intensively managed sites downstream, allowing for a comparison the the Philippine situation.

The three sites have different social and political dynamics. Malaysia is democratic through a parliamentary system, but dominated by one party which depends on support from rural voters and thus favours and pampers rice farmers, while Vietnam is socialist, farmers work in communes under an authoritarian system. The Philippines practice free (albeit corrupt) democracy through a presidential system and policy change can be difficult. Land tenure, extension and other social systems are also quite different, which provides opportunities to address issues related to Payments for Ecosystems Services “PES”. These three countries provide opportunities to make comparisons since common methods will used to address the following questions:

1. What are the key biodiversity issues and ecosystem services (in particular nutrient cycling, natural biological control and pollination services) and how they are affected by the rice cultivation intensity and land use? What are cross site similarities, differences and learning opportunities?
2. What kinds of diversifications in terms of habitats, vegetations and land use influence biodiversity and ecosystem services most? Also what are barriers and constraints important in the difference sites?
3. What kinds of landscape level adjustments can be implemented to enhance biodiversity and ecosystems services under the different political and government structures?

4. What are the differences and similarities in farmers' knowledge, attitudes and practices, the barriers to adoption and incentives related to biodiversity conservation practices?
5. What are the key features in the three socio-political systems that are important in implementing structural adjustments to favour biodiversity and ecosystem services? For example, how can a PES system be implemented or modified under the 3 different systems?
6. What are the important communication strategies and processes (at farmers, local government and national policy levels) required to initiate changes to favour the adoption of policies and practices to favour biodiversity and ecosystem services conservation in the 3 different sites?
7. The participants from the 3 Asian sites will develop a learning alliance, sharing experiences, experimental techniques and data.

6.3.2 Protocols for the field assessments

The standard assessments in ITS as well as ETS will often relate to the same factors, but the level of intensity will be very different and for the ETS as only a subset of simplified methods for some of the core physical and social parameters will be applied (see Table 6.2 for overview).

Detailed descriptions of protocols

Site characterisation. Aerial pictures as well as remote sensing data will be used to characterise the land use structure of the investigation sites. For the characterisation of ETS information about geology, relief, climate and soils will be collected from available maps and available databases. ITS will be characterised by soil analysis.

In both cases, existing data on the economic situations, and the ethnic and cultural composition will be identified in existing national data bases; for ITS also social structures, values and identities will be mapped by field research.

Table 6.1: LEGATO Areas of investigation (AoI), Intensive Test Sites (ITS) and hypothesised categorisation of land use intensity, structural diversity and cultural identity

LEGATO Areas of investigation (AoI) and Intensive Test Sites (ITS)	Land use Intensity			Structural Diversity			Cultural Identity		
	low	med	high	low	med	high	low	med	high
AoI: Philippines Luzon: Nueva Ecija; Ifugao									
ITS 1: Los Banos, Laguna			X		X		X		
ITS 2: Munoz, Nueva Ecija			X	X			X		
ITS 3: Lagawe/Kiangan, Ifugao		X				X		X	
ITS 4: Banaue, Ifugao	X					X			X
AoI: Northern Vietnam: Red River									
ITS 1: Halong	X					X			X
ITS 2: Hanoi			X	X			X		
ITS 3: ca. 100-150 km north-west of Hanoi		X			X			X	
ITS 4: Sapa		X				X			X
AoI: Southern Vietnam: Mekong Delta									
ITS 1: Mekong Delta South West			X	X			X		
ITS 2: Mekong Delta North East			X		X		X		
AoI: Malaysia, Muda Irrigation Scheme									
ITS 1: Muda central			X	X			X		
ITS 2: Muda intermediate			X	X			X		
ITS 3: Muda peripheral		X			X		X		
ITS 4: Muda edge of scheme		X				X	X		

Pollinator field assessments will be performed using pan traps and trap nests according to the standardised protocols developed by Westphal et al. (2008). Sampling will take place in relation to the crop cycles in Asia. Scale-dependent effects of local biodiversity and regional land use changes on species richness and abundance will be analysed with respect to species-specific traits. Further, the relationship between climatic conditions and pollinator community composition will be analysed.

Table 6.2: LEGATO assessments in extensive test sites (ETS) and intensive test sites (ITS)

	ETS	**ITS**
General		
• Characteristics landscape structure	Diameter of 100m around spot of investigation; 3 different larger diameters from aerial photography and/or remote sensing data; Data collection about geology, relief, climate and soils from available sources	Complete characterisation of the 4x4 km² area; 3 different larger diameters from aerial photography and/or remote sensing data; Characterisation of soils.
• Questionnaires on socio-economic frame conditions	Household/production structure, yields, pesticide and fertiliser use, Ethnic group, land ownership/use rights structure, market integration, income situation, land use intensity, landscape value criteria, level of subsistence	ETS plus income sources and expenditures, agricultural input expenditures, income structure, spending priorities, dominant sources of information, aspirations/priorities for change and for conservation, decision driving forces (tradition, state regulation, religion, gender roles,…)
ESF/ESS Strand 1 (Nutrient Cycling & Crop Production)		
• Nutrient status in rice fields and surroundings (incl. water bodies)	Multi-element analysis with ICP-MS. This will allow to analyse the nutritional status of the plants and the soil as well as the quality status of waters.	Analysis of representativ soil characteristics
• Nutrient and matter fluxes		Measurements of nutrient and matter fluxes of soil-plant and soil-water pathways.
• Diversity and composition of native and introduced field weeds	Species abundance measures	Samples, transects
• Plant diversity of field surroundings	Surveys	Scheme-based samples
• Quantification of soil structure	Quantification of macroaggregates	Quantification of soil aggregate size distribution
• Assessment of decomposer diversity		Extraction from soil and litter sample
ESF/ESS Strand 2 (Biocontrol & Pollination)		
• Pollinating insects in rice fields and surroundings	Sweepnet	sweepnet, pan traps, trap nests for cavity nesting bees and wasps, pitfall traps
• Assessment of important pest insects and intensity of damage • Assessment of predator and parasitoid biodiversity	Visual assessment along transects	Assessments of phytometer crop plants (see 6.3.3.); Smal plot experiments; Light traps, yellow pan traps, sticky boards and suction sampling

Table 6.2 (continued):

	ETS	ITS
ESF/ESS Strand 3 (Cultural Identity & Aesthetics)		
• Assessment of stakeholders' perception of the landscape	Assessment (questionnaires and participatory rural appraisal) along the land-use intensity and structural diversity gradient	Socio-cultural epxeriments along the land-use intensity and structural diversity gradient
• Assessment of valuation and preference by stakeholders of the landscape and related diversity	Assessment (questionnaires and participatory rural appraisal) along the land-use intensity and structural diversity gradient	Socio-cultural epxeriments along the land-use intensity and ecological engineering knowledge gradients

Litter and soil samples will be taken to extract the meso- and macrofauna and will be sorted to morphospecies and functional groups. For this, we will use rice straw from fields and naturally occurring litter in the surrounding plant communities as well as corresponding soil samples. Soil fauna will be sampled once or twice per year (depending on the flooding regime) across 3 years from the crop fields and their surroundings along gradients of land use intensity and structural diversity using a modified Berlese-approach. At the same ITS, insect species will be sampled by using a set of complementary methods (see Table 6.2) and determined to a level which allows the separation of predators and herbivores. Feeding damage will be quantified as percentage leaf damage and attack rate using phytometer crop plants in close cooperation with SP3 in the ITS (see 6.3.3). These phytometer plants will be also established in the surroundings to disentangle the effects of landscape characteristics and agricultural methods. In the ETS, a visual assessment of levels of crop damage by pest insects will be conducted at larger spatial scales along landscape transects. These assessments will be done at least every three weeks during two crop cycles. Species richness and abundance of decomposers and insect species will be related to vegetation composition and characteristics of land use intensity and structural diversity (assessed by project partners). We will use this information for a general assessment of the effects of land use on invertebrate diversity and possible relationships with productivity and herbivore pressure by insect pests. In the analyses, we will focus (1) on the potential role of decomposer fauna as indirect driver of biocontrol of pest species via the predator level, and (2) on the relationship between decomposer diversity and decomposition as well as nutrient release from litter (rice straw, weed litter; information from WP3). Together with the results from WP3, this information will be used to develop a biological indicator system for soil and ecosystem functions as well as ecosystem services in the investigated agroecosystems for further integration into concepts on sustainable land use.

Plant species composition of each ITS will be analysed for fields as well as field surroundings. Sampling of plants in field surroundings will be once in representative semi-quantitative surveys, that of plants in the fields will be twice per sample plot (in subsequent years and meeting the crop-cycle phases). Plant species will be identified and categorized as native to the AoI or alien/introduced. In order to assess the plant diversity potential soil seed bank analyses will be performed in each AoI, selecting ITS with different land use intensities. Soil seed bank will be sampled once, and the seed bank will be assessed using the seedling emergence method. Functional group analysis will be applied to our data on plant species above-ground and below-ground (seed) diversity.

Using data bases and literature, existing vegetation and soil seed bank of field surroundings will be checked for the presence / absence of host plants of pollinators and biocontrol agents, and alternative host plants of crop pests. These data will then be analyzed with respect to effects of landscape structure (e.g. patch size and isolation) on patch occupancy by these plant species, and linked to experiments investigating the role of regional factors (e.g. dispersal limitation) vs. local factors (e.g. resource availability) on plant community diversity and composition.

Stakeholder perception, preference and valuation of ESS and ESF will be analysed in the selected countries along the land use intensity and structural diversity gradient. To this aim socio-cultural values (equity and cultural perception) in terms of cultural landscapes will be determined. Besides monetary valuation of yields, damage and avoidance cost, we will in particular examine non-material values (e.g. religious, cultural, aesthetic and recreational) that can be attached to the agricultural systems and related ESS/ESF. We will perform comparative studies in all three investigation countries. For the ETS methods we will draw from an existing pool of proven methods, such as questionnaires (semi-structured interviews) and participatory rural appraisal methods. The audio-visual testing of landscape related affections can draw on established experience in the German sites, and will be adapted to the local circumstances for the Asian sites. For the ITS socio-cultural experiments will be applied (see WP 3.3).

6.3.3 Protocols for the experiments

Experiments in relation to Strand 1 (Nutrient Cycling & Crop Production)

Using a litter bag approach we will experimentally investigate the **contribution of decomposer fauna to decomposition processes and nutrient cycling** on the ITS. These investigations will be made using rice straw during non-flooded phases (e.g. phases of intertillage crops) as well as during flooded phases and using naturally occurring litter in plant communities in the surroundings. For this, we will use litter bags with different mesh sizes which allow or restrict the access of the decomposer fauna to the litter material. Litter bags will be placed in the field and the loss of elements (nitrogen, carbon, silica) as well as the disappearance rate of organic matter will be assessed. This will be done in agricultural fields as well as in the surroundings on ITS along gradients of land use intensity in the different regions. Since the quality of litter is a crucial component of decomposition processes and may also be affected by specific site conditions, this approach will be run with both a common standard litter for all sites and with site specific crop litter. In addition, crop litter from the specific ITS will be sampled and used for a common garden experiment in each region to assess the impact on land use within the regions on the quality of organic matter. We will use data from the field assessment of decomposer diversity to relate observed decomposer diversity to nutrient dynamics and decomposition of organic matter. Using these data, we will be able to assess a functional link between land use, structural diversity, biological diversity and important ecosystem functions (nutrient cycling, fertility of soil). The use of productivity measures, and its monetary value, as the response variable, will enable us to position the decomposer community into the context of benefits provided by ecosystems.

Transplant experiments with litter and soil samples between different land-use types will be performed within selected study regions. This will allow the comparison of decomposition rates of transplanted versus control treatments to test for adaptation of the decomposer fauna to land use types.

Experiments in relation to Strand 2 (Biocontrol / Pollination)

Using the data from field assessments we will identify important crop pest species which are amenable for experimental manipulations and may cause serious reductions in crop productivity. Candidate species for these investigations are rice stem borers and several phloem-sucking hemipterans. At least one important model system (crop species + pest species) will be identified for each Legato main region. We will establish phytometer crop plants which will be planted into crop fields and their surroundings. Insect herbivores will be excluded from half of the phytometer plants using controlled application of insecticides. Further, the impact of fertilization with nitrogen and silica is expected to influence the performance and attack rate of pest insects as well as the resistance of plants to herbivory. We will therefore further include nitrogen fertilization and silica fertilization in the experiment (see nutrient related tasks 3.2.1 – Partners MLU and UFZ). Insect herbivory and attack rates on non-treated plants will be assessed every other week (see also WP2). At time of harvest, biomass production and yield of treated and non-treated plants will be examined. This allows the assessment of the extent of damage and its monetary value depending on landscape characteristics and land use practices.

We will experimentally evaluate the importance on food web interactions between decomposers, predators and pest insects for natural biological control. On a few selected ITS sites differing in landscape structure and land use intensity we will manipulate resource supply (plant material) and pest insect control by predators. Using litter addition (rice straw vs. other plant litter) on experimental plots we will test the hypothesis that favouring the decomposer fauna by an increase of resource supply has positive effects on predators leading to a more efficient suppression of crop pests. In a split-plot design we will exclude predatory insects by means of caging to assess efficiency of predators for biocontrol. Additionally, by spraying sub-plots with insecticides we will assess the resulting net damage of pest species on standing crop as a result of changed intensity of trophic interactions between decomposers, herbivores and predators. By comparison of the results from differently structured landscapes we will examine if structurally more diverse landscapes show a higher level of natural biocontrol due to higher diversity of the decomposer and/or predator subsystem.

Using field experiments based on standardized protocols replicated across the ITS sites (in particular seed addition experiments), we will analyze whether plant species diversity and composition of field surroundings (e.g. abandoned fields, grasslands, or other semi-natural or natural habitats) is governed by dispersal limitation from the regional species pool, or by local abiotic and biotic factors (e.g. soil resources or herbivores). Special attention will be paid on those plants species which are known to be host plants of pollinators, biocontrol agents, or crop pests. In addition, the potential and the realized species composition of field surroundings will be evaluated for their aesthetic value, which will be done in collaboration with Strand 3.

Experiments in relation to Strand 3 (Cultural Identity / Aesthetics)

Experiments on socio-cultural services will be an iterative and participatory process, limited by the project resources as much as by the “carrying capacity” of local stakeholders regarding social science investigation. Unlike many life science experiments they cannot be defined ex ante in any detail without sufficient knowledge of the local conditions.

Thus a necessary first step is a pre-study to collect information about objective factors (e.g. subsistence level, income situation, educational level, health status, etc.) from data and from observation and individual ad-hoc interviews, plus a more systematic investigation of subjective perceptions of the situation, the level of satisfaction resp. the desire for (which kind of) change, including to identify which are the services recognised by the local stakeholders, how are they defined and contextualised.

Building upon this information, more specific questions can be developed and the corresponding questions chosen, regarding the importance of different services, the future expectations, the observed / experienced and expected challenges.

In social science research, the basic idea of an experiment is that two groups are set up for comparison, one with treatment and one control group (no treatment). There are situations where the comparisons occur naturally (e.g. gender), namely 'naturally occurring treatment groups'. One example could be the comparison between male and female groups on the topic of local identity. As the research on cultural ecosystem services is still in its infancy (see chapter 5.1.2 strand C: cultural services) we apply qualitative social research methods rather than going for statistically significant quantitative data collection. Qualitative social research better reflects on the ground reality and considers in more detail stakeholder and decision-making processes. The methods of choice include questionnaire surveys, and in particular participatory censuses will be used for data collection.

Generally participatory censuses include social mapping and social learning regarding issues which have to be defined in the pre-study mentioned above. Censuses are aimed at taking a closer look at the individual household, including inducing changes in individual behaviour in a social context. The information collected range from demographic details (age, gender), ethnic group details (religion), productive assets (land holding, livestock), and health-related information (diseases, malnourished household members). The major way of doing participatory censuses are social map method and card method. Major outcome of the methods applied are maps and card-mosaics, respectively. The censuses are also the basis for social learning experiments, leading to changed behavioural patterns if successful.

Thus one type of experiments will consist of asking different groups to respond to a series of scenarios and compare the answerers, analysing the kinds of differences emerging between regions and cultures, and correlations to gender, social status and economic situation. Others will analyse the cultural patterns and emotional relationship to landscape and biodiversity by using audio-visual means. Again others will aim at inducing behavioural changes in land management practices; they provide the bridge between social experiments and implementation.

The data generated from socio-cultural experiments will be used for formulating hypothesis concerning local identities and their relations to natural and cultural landscapes of different local stakeholders. These hypotheses in turn serve as basis for discussion during the future search conferences and the scaling-out and scaling-up of research results in the implementation phase (see chapter 6.5.1). This stakeholder-based method is applied in our project in order to enhance social learning among the stakeholders about the major project outcomes.

As far as stakeholder information is needed as an input to other strands of research (e.g. information about past pesticide use intensities), the corresponding questions will be integrated into the questionnaires. This requires a close collaboration between natural, social and cultural scientists: the former have to define an information need, the latte to design questionnaires which deliver the information demanded (maybe in an encrypted form needing collaboration again to bring the information into a shape usable by natural scientists).

6.4 Integration (across ESF/ESS strands)

The results from field assessments and experiments will be linked via four core elements: 1) valuation, 2) indicator and data base development, 3) comprehensive ESS assessment, and 4) modelling approaches. This integration allows for a consistent evaluation of scenarios across sites and time.

6.4.1 Valuation

Ecosystem functions are system phenomena, since some of them are valued by humans, these are considered ecosystem services. Thus valuation of ESF/ESS primarily refers to ESS. Monetary valuation can be based on real market effects (materialised or expected), on hypothetical ones, or on both. Real market effects have the strongest alerting effect, as they signalise (potential) factual losses and payments, and thus real losses in income and welfare, beyond hypothetical ones assessed on the basis of revealed or stated preferences. Thus damage cost and management/repair costs will be in the focus of the monetary valuation, providing an estimate of necessary expenditures or lost income due to alterations in ecosystem functions. These kinds of market costs occur in all three strands of analysis, but it is to be expected that they are most significant regarding production (damage cost) and regulation services (repair/management cost).

As human welfare, and even more so well-being are complex states which cannot exclusively be described by monetary measurement, non-monetary valuation is an important complement to monetisation. It can be done by using objective welfare indicators, comparing the state of the system under analysis to some externally set, but empirically founded objectives, and by subjective assessments investigated by field research using semi-structured interviews and questionnaires. Whereas monetisation and objective measurement can be done as desktop research based on available data (some complementary data mining will probably be needed), subjective assessments are labour and time intensive and require significant resources. Within LEGATO we will combine both approaches within WP 4.1.

6.4.2 Indicator development and modelling

An important tool to characterise and communicate the state of the environment, social as well as economic conditions will be the integrative indicator framework system, which will be developed in WP 4.2. This framework evaluates structural and functional indicators on biodiversity, ecosystem processes as well as socio-economic conditions and allows assessing the consequences of land use changes. The components indicated in WP 4.2 include external constraints (such as climate, technology, and policy which are part of the scenario exercises in WP 4; thus complementary indicators for these factors will be available), external and internal drivers (e.g. motivations of actors and economic activities as analysed in the socio-cultural and the valuation research), and the resulting pressures on environmental compartments, induced changes in the ecosystem state, and the structure, function and integrity. These changes are in turn closely related to the human wellbeing, and WP 3.3. will provide evidence of these linkages. The development of the indicator framework will be conducted in close collaboration with the valuation and the socio-cultural research strands (which can contribute specific indicators), and in particular with the model evaluations in WP 4.4. Here, the generic model of terrestrial ecosystem dynamics LPJmL (Sitch et al. 2003, Bondeau et al. 2007), will be adapted for the study sites and extended by feedbacks between (semi-)natural systems and the embedded agricultural systems. LPJmL simulates the dynamics of (semi-)natural ecosystems and agricultural systems using basic process descriptions about the relation between atmospheric conditions, soils, and land use. One important step in this project will be the integration of feedbacks between the two systems into LPJmL to link regulating and provisioning services of (semi-)natural ecosystems to ecosystem services of agricultural systems, and therefore to account for ecological engineering effects. This will be done in collaboration with WP 2 and WP 3, as well as with the stakeholder dialogue in WP 1.1. Resulting ecosystem processes such as net primary production, crop production, carbon storage, or water regulation will complement the findings of WPs 2 and 3, thus contributing to an integrative indicator framework system describing not only the state of the environment, but also its socio-economic context.

The developed indicators will be used to illustrate the risks and opportunities of different production systems. This allows for pinpointing the consequences of land use regimes and climate change consistently across ESF/ESS strands. Especially, it will be possible to use the indicators when comparing results from scenarios, historical recordings and experiments to assess the resilience and adaptability of the system in the light of the systems' behaviour potential. These results will be presented and discussed with local stakeholder in order to find out about their future preferences. Identifying buffer mechanisms will help to find appropriate management tools and policy instruments. Due to the generality of LPJmL studies and the adaptability of the indicator framework, these studies can be performed across regions to not only gain insights into local interactions between land management, climate change and ecosystem services, but also insights on different bio-geographic regions.

6.4.3 Overall ESS assessment

The LEGATO case studies will also serve to assess the linkages between human and environmental subsystems. In this context, the direct link between pressures by land use or climate change, the resulting impacts on ecosystem services and the implications for the human economy and well-being will the synthesised in WP 4.3. In particular the identification of perceived services and the service providing units for all ESS will allow a comparative analysis of overlaps, synergies and trade-offs.

Especially, the spatial de-coupling of ecosystem service demand and supply will be evaluated, which arises when service demands (e.g. from urban centres or industrialised northern countries), for example in the context of food provision, are fulfilled in rural, less developed regions (Burkhard et al. 2009). Based on supply and demand evaluations, local and regional ecosystem services balances as well as service flows can be calculated (Burkhard & Kroll 2010). Ecosystem service balances provide important information for environmental and resource management as they give information on the degree of a society's self-supply vs. imports of goods and services.

6.5 Implementation and Dissemination of LEGATO results

6.5.1 Implementation

The step from analysis to implementation is initiated in the social learning component of the socio-cultural experiments. The farmer participatory research (FPR) approach involves motivating farmers to engage in experiments in their own fields so that they can learn and adopt new technologies (Bunch 1989). This step, sometimes known as innovation evaluation (Rogers 1995) is essential for communication as well as for initiating diffusion. The main advantage of this approach is that farmers “learn by doing” and decision rules are modified on the basis of direct experience.

For instance, in the Philippines and Vietnam, this approach was used to change farmers’ perceptions about leaf feeding insects and their insecticide decisions (Heong & Escalada 1997). Farmers were presented with conflict information framed in the form of a heuristic and invited to test if the new information was true, i.e., spraying insecticides in the early crop stages is generally not necessary. This heuristic, based on many years of scientific research (Way & Heong 1994), is in direct conflict with farmer beliefs and requires social learning to be translated into sustained behavioural changes.

For this behalf, LEGATO consortium members developed participatory tools that can help farmers modify their cognition. One of those tools consists of two steps, first to obtain information from farmers about the problem and then transform the information into gains and losses to facilitate discussions. This participatory tool has been evaluated for its effect on farmers' cognition and decisions on stem borer control in the Philippines with the result that participating farmers made adjustments to their heuristics and reduced sprays (Escalada & Heong 2004).

A further method to be applied in terms of social learning is the accomplishment of future search conferences. This is a well-established method within the social sciences based on the work of Weisbord (1995). During a several days-event participants, split in various groups, will explore commonalities which can be derived from the model results to build consensus on the major outcomes of the LEGATO project. This process will further help to develop shared perspectives on what is a desirable irrigated rice management strategy for the region under concern, the context necessary for their implementation and their impact on societal systems. The aim here is to foster the emergence of a common vision of stakeholder's preferred future.

6.5.2 Dissemination

The dissemination activities will be largely based on a general communication strategy which will be prepared around the 4th month of the project (June 2011). The communication strategy will be based on seven fundamental principles and will be structured to respond to the specific challenges coming out of the project's goals:

(1) to go beyond conventional means of dissemination of project results to academic societies and policy makers to reach the widest possible specialist and especially non-specialist audience among the end users through a combination of *Global Information Access* and *Local Knowledge Delivery* principles.

(2) to use both *passive* and *active* dissemination methods;

(3) to adapt contents and methods of dissemination according to the needs and specifics (e.g., educational level, different background, different incentives) of the various target groups – specialists, policy makers, managers, stakeholders, conservationists, local farmers, etc.

(4) to reach a multi-language and multi-cultural community of users based in two geographically remote regions, Central Europe and Southeast Asia;

(5) to ensure and strictly adhere to the principles of open access to publicly funded research;

(6) to extend the Web presentation of the project results by implementing up-to-date technologies (Web 2.0 and semantic Web principles) and by integrating smartphones as data collecting and presentation devices so that to engage potential users.

(7) To involve the public into the project by using citizen science tools for data gathering (observations, photo documentation, polls, discussion boards, identification aids) and open access data presentation.

One of the most important challenges to address will be to disseminate project results to local institutions and traditional societies of Southeast Asian countries. LEGATO will coordinate with the GLUES partner responsible for the GeoData Infrastructure (GDI) to ensure that GDI meets the requirements of LEGATO stakeholders and, conversely, that LEGATO dissemination matches the concepts of GDI. The commitment of CABI SE Asia to LEGATO will guarantee a smooth project implementation through CABI's member countries and networks established during last decades.

Besides these official and formal information dissemination channels, LEGATO will also make use of established but informal mechanisms for its scaling-out, the horizontal spread of information. For this to be effective, the modification of cognition through externally supported reflection (see above) is an important condition as only then this next step on the impact map can be taken. To reach this goal, no new networks will be established, but existing communication channels will be systematically used. In the Mekong delta, for instance, farmers of the local region traditionally meet for information exchange in the off-season, self-organised on a rather small scale. If someone has brought about important achievements, he is declared a "local hero" and sent on to the farmers' meetings in other localities of the greater region. We are confident that ecological engineering will produce "local heroes" which spread the concept by word of mouth. Together with organising discussions with administration officials involved as stakeholders, and the public presentation of results in each capital, this is a key element of institutionally anchoring the project results in framers' day-to-day practice and everyday routines.

7. Structure of the project, project management/coordination, type and intensity of cooperation of the partners involved

7.1 LEGATO project structure

Within this chapter we present a more detailed level of the LEGATO project structure (for a more general overview see chapter 6.1 and Fig. 6.3).

Fig. 7.1 contains all the research elements on workpackage and sub-workpackage level and also shows the feedback loops (graphically incorporated in a slightly different way than in Fig. 6.3).

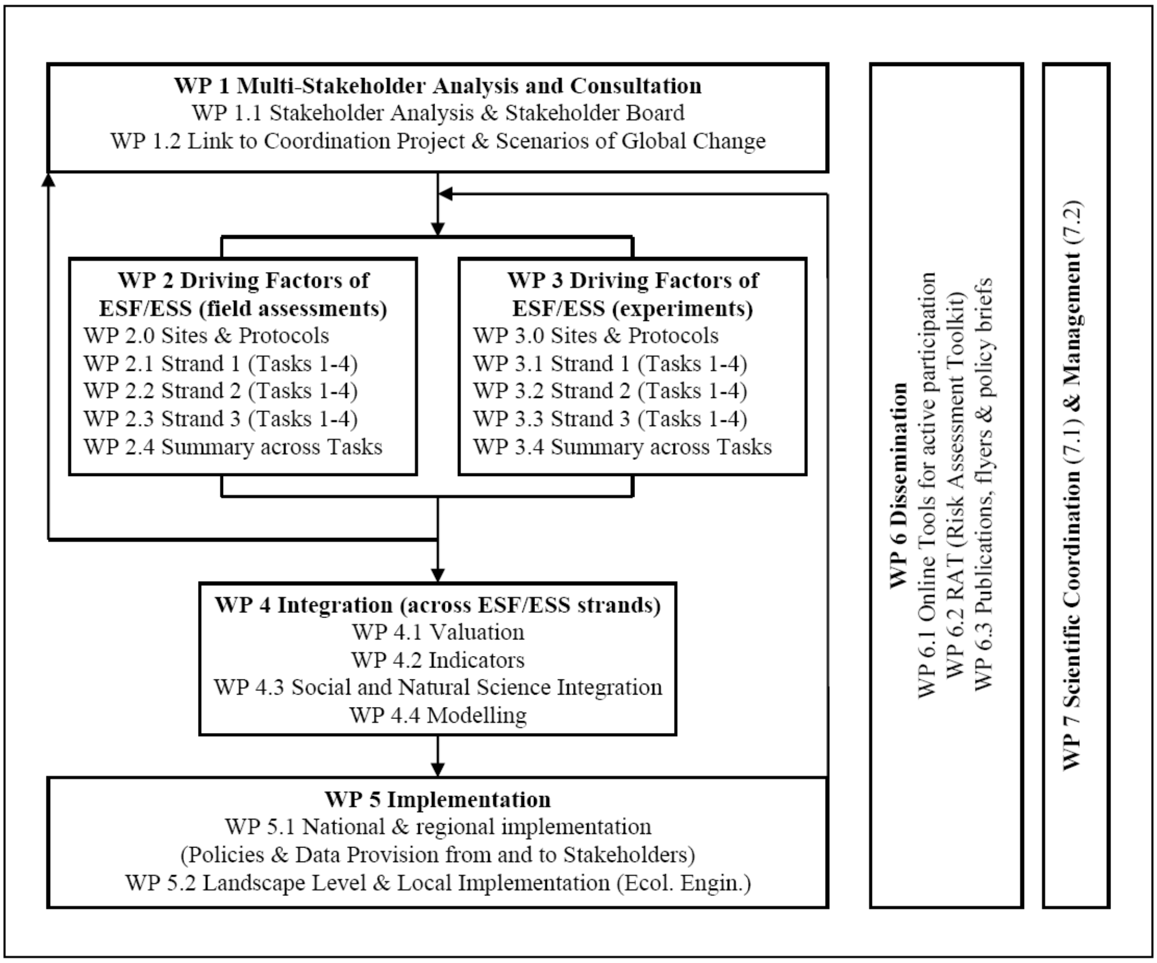


Figure 7.1: LEGATO detailed structure and work flow
(Task 1: Land use; Task 2: Biodiversity; Task 3: Climate; Task 4: Social system)

Research in WPs 2-5 is based on the **stakeholder involvement** in designing and implementing social and natural science research in LEGATO. As WP 1 also contains the **link to the Coordination project (GLUES)** as well as decisions on the selected **scenarios of climate and land use change** (both in WP 1.2), it will be from there that adjustments to new and developing requirements (e.g. scenario adjustments) will be implemented into the LEGATO research. While further refinement will surely result from this feedback process, we developed a first more detailed structure as a starting point, based on exchanges with many of the stakeholder groups involved. Particularly results of consultations in all study areas, which were conducted from August to early October 2010, have contributed considerably to the development of a realistic work plan which at the same time should yield relevant and innovative results.

Within WPs 2 and 3 the detailed **assessment of impacts of environmental pressures on the selected ESF/ESS strands** is foreseen. First the detailed site selection and protocol refinement will be performed in WPs 2.0 and 3.0. Within WPs 2.1-2.3 and 3.1-3.3 for each of strands the impact of 1) **Land use**, 2) **Biodiversity**, 3) **Climate**, and 4) the **Social System** will be dealt with (see Fig. 6.2 for a graphic representation of the scientific approach). The final integration across tasks will be achieved in WPs 2.4 and 3.4, respectively, where the integrated summary of the impacts of different pressures on each of the 3 ESF/ESS strands will be presented.

The next level of **integration** – across the ESF/ESS strands – is the main objective of WP 4, in which the core elements are 1) **Valuation**, 2) **Indicator development**, 3) the final stage of **natural and social science integration**, and 4) **Modelling** approaches for the creation of the larger picture under different scenarios of future development.

For the **implementation** (WP 5) we have chosen two major levels: 1) the **national and regional implementation**, which relates to general policies or to the data provision from stakeholders (active participation e.g. through a) online tools and/or b) standard assessments, like light traps for monitoring key pest species) or to stakeholders (e.g. data and interpretations on larger scale developments of indicators), and 2) the **landscape level and local implementation** guidelines, i.e. the application of **Ecological Engineering**).

Dissemination activities (WP 6) are planned throughout the entire project duration. While here we will develop online tools for active participation of the public at large (which is one stakeholder group) in the course of the project, work on a Risk Assessment Toolkit (RAT) will be a particular focus in the second half of LEGATO. Scientific and popular **publications** can be expected from the second year onwards, while **flyers** will be produced at particular stages of LEGATO (one project flyer after ca. 1 year; and rather towards year 4 and 5 specific information flyers for ecological engineering, RAT and/or online tool applications). **Policy briefs** are to be expected from year 3 onwards. All of these broader dissemination activities will have to be done in the relevant languages of the participating countries (i.e. English, German, Vietnamese).

The overall project **coordination and management** is the task of WP 7, with an overview presented in chapter 7.3.

A more detailed account of the planned work is presented in the description of the individual WPs in chapter 11.

7.2 LEGATO timing of work packages and their components

Figure 7.2 shows the temporal organisation of the workpackages. We have decided to go for the inclusion of feedback loops, thus many WPs have to have a rather long duration. As all of these WPs include social as well as natural science elements, we also did not follow the simplified approach of first doing natural science research and then concentrate on social science and implementation, this rather has to go hand in hand nearly throughout the entire project duration. In the course of LEGATO, particularly WP 1 is gradually replaced by WP 5.

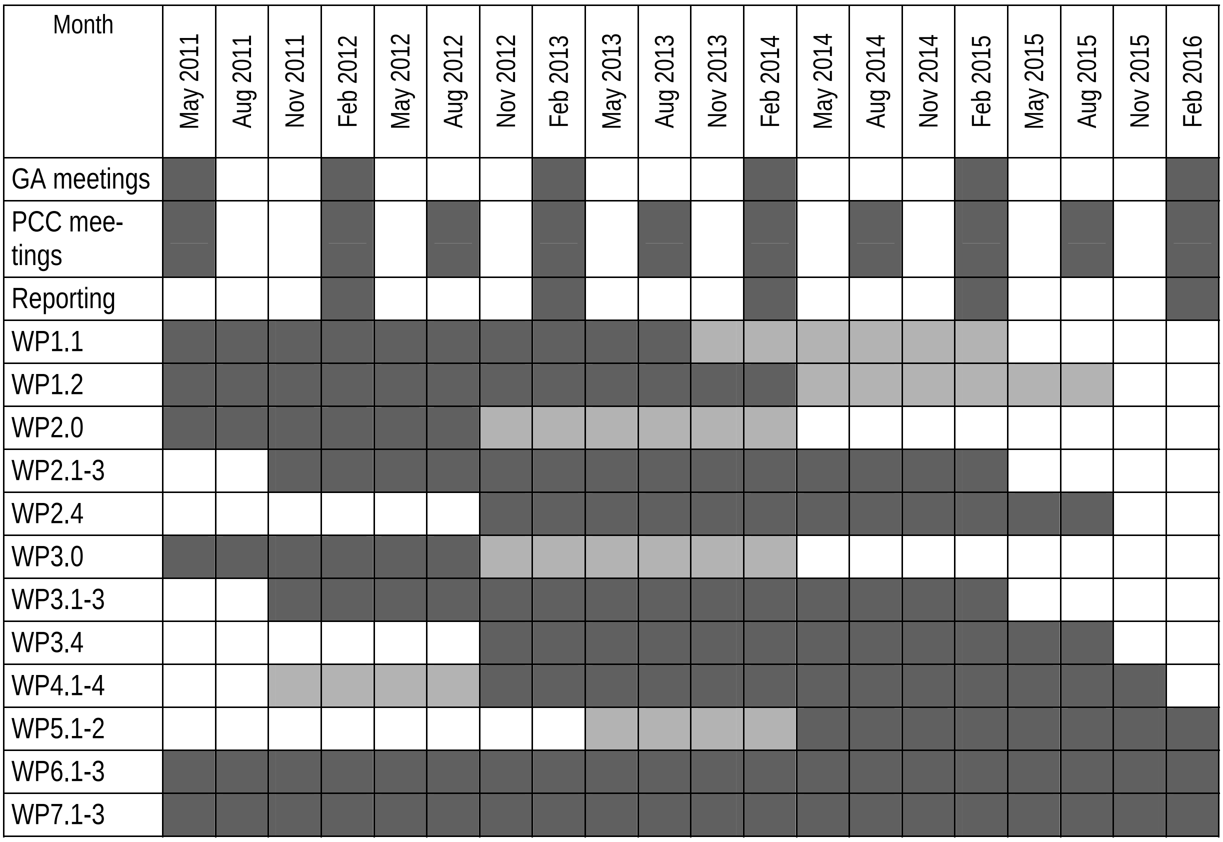


Figure 7.2: LEGATO temporal organisation of the work packages
(dark grey areas: intensive work; light grey areas: preparatory or concluding work)

7.3 LEGATO coordination and management

The project structure of LEGATO also is reflected in the project coordination and management, which is summarized in Fig. 7.3. It contains all central elements of management and decision-making. We have chosen a simplified approach compared to previous projects where the LEGATO coordination team already has proven to be able to successfully and efficiently coordinate much larger consortia (in particular the ALARM project with 250 colleagues and 68 partner organisations from 35 countries, Settele et al., 2005).

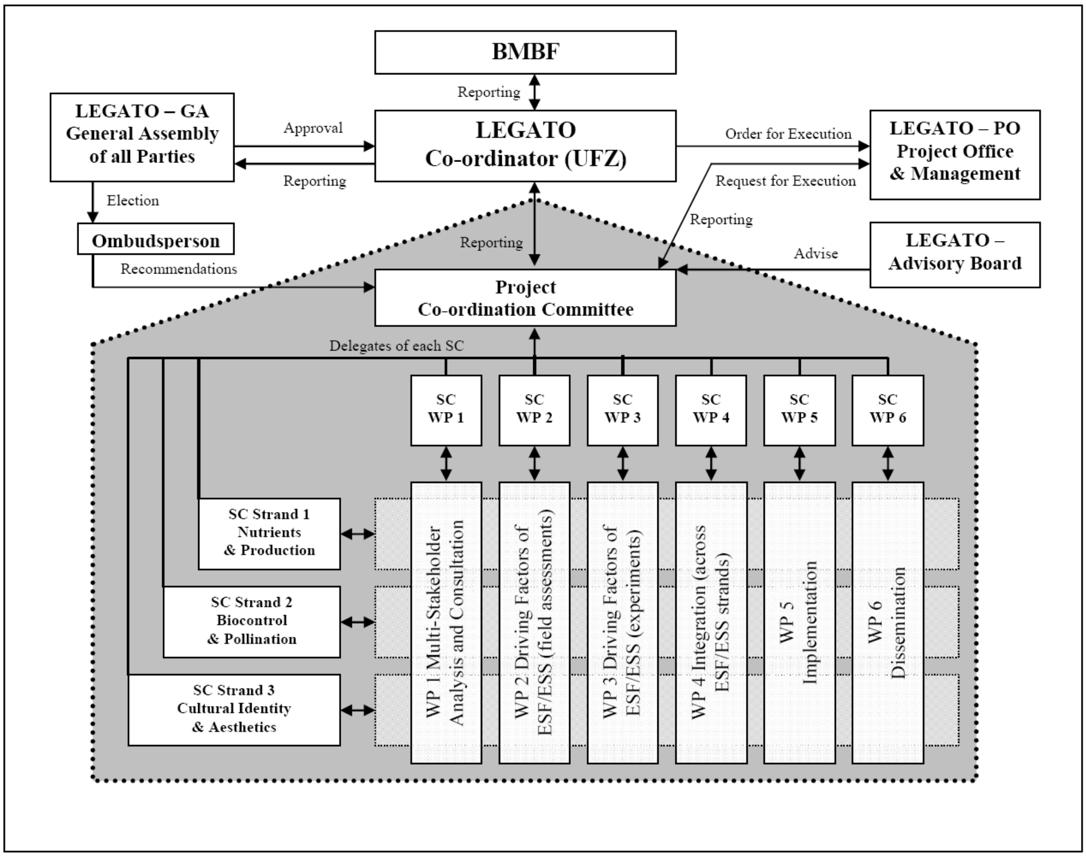


Figure 7.3: LEGATO management structure

7.3.1 Organisation of the project

LEGATO requires very close integration across thematic work packages as well as across different research sites/areas, and this has been carefully considered in the proposed organisation structure. The co-ordination structure of LEGATO is based on experience gained from managing other major research projects with similarly rigorous requirements. Core elements of the LEGATO co-ordination and management structure are the **LEGATO-PCC (Project Coordination Committee)** and the **LEGATO-Project Office (PO)**, both headed by the Project Coordinator.

The **LEGATO-PCC** (see Table 7.1) is the central body responsible for the scientific operational co-ordination. It is in charge of the necessary decisions in coordinating and administrating the project. The PCC consists of the Coordinator (Josef Settele, UFZ) and one more member of the coordination team (NN, UFZ), and 18 delegates of the different Steering Committees (SC). These delegates can designate deputies from within their SC (see Table 7.2), if they cannot participate. Besides the WPs, each ESF/ESS strand is represented through adequate key scientists.

Table 7.1 Members of the LEGATO PCC
(Coordinator and Steering Committee delegates)

Strand / WP Steering Committee	Delegate(s) of Steering Committee in *LEGATO*-PCC	Germany (Europe)	SE-Asia	Natural Science	Social Science	Stakeholder	SME
LEGATO Co-ordinator	Josef Settele (UFZ) & Benjamin Burkhard (CAU)	2		1	1		
Strand 1 Nutrients & Production	Reinhold Jahn (MLU) & Ho Van Chien (MARD; Vietnam)	1	1	1		1	
Strand 2 Biocontrol & Pollination	Catrin Westphal (UGOE) & Gertrudo S. Arida (PhilRice)	1	1	1		1	
Strand 3 Cultural Identity & Aesthetics	Susanne Stoll-Kleemann (UGR) & Monina Escalada (VSU; Philippines)	1	1		2		
WP 1 Multi-Stakeholder Analysis and Consultation	Joachim Spangenberg (UFZ) & Felix Müller (CAU)	2		1	1		
WP 2 Driving Factors of ESF/ESS (field assessments)	Ingolf Kühn (UFZ) & Le Xuan Canh (IEBR; Vietnam)	1	1	2			
WP 3 Driving Factors of ESF/ESS (experiments)	Roland Brandl (UMAR) & Dao Thanh Truong (CEPSTA; Vietnam)	1	1	1	1		
WP 4 Integration (across ESF/ESS strands)	Kirsten Thonicke (PIK) & Joan Martinez Alier (UAB; Spain)	2		1	1		
WP 5 Implementation	Kong Luen Heong (IRRI; Philippines) & Mohd Norowi Hamid (MARDI; Malaysia)		2			2	
WP 6 Dissemination	Lyubomir Penev (PENSOFT; Bulgaria) & Norbert Hirneisen (S4Y)	2				2	2
Total		13	7	8	6	6	2

The membership of the PCC (Table 7.1) comprises 2 SMEs, 11 representatives from Germany, 7 representatives from South-East Asia and 2 representatives from other countries (Spain, Bulgaria). 8 of these members are natural and 6 are social scientists. These are complemented by 6 members who rather have a role as stakeholder than as scientist.

An appointed LEGATO coordinator/ manager attends PCC meetings (but does not vote). He/she will monitor project progress on a daily basis, by issuing early reminders about Deliverables and informal contacts with LEGATO scientists about development of Deliverables, including delays. In the case of significant delays he/she will inform the coordinator, his deputies, and the LEGATO-PCC, suggesting appropriate action in order to support LEGATO members in achieving the predefined goals.

The **LEGATO-PO** consists of the project management team which will comprise experienced UFZ staff members, who successfully have cooperated with the coordination team in several projects and who are known to guarantee smooth procedures and - equally important - a harmonic working atmosphere. Furthermore, administrative staff and the UFZ Department of Public Relations are members of the PO. A full time secretary is employed at the Department of the co-ordinator and will provide additional administrative support for the PO for correspondence, project organisation, workshops, and meetings. The PO members guarantee adequate administrative and technical project controlling and take care of financial, budgetary, legal, and administrative management matters.

PO members will work closely with the LEGATO co-ordinator. As a large research institute, the UFZ administration is highly experienced in the management of major research projects. As examples, we may highlight the successful scientific co-ordination of the EC funded biodiversity research projects “FRAP” (FP 5, RTD project; 13 partners), “MacMan” (FP 5, RTD project; 30 partners), “EuMon” (FP 6, STREP; 16 partners), and “ALARM” (FP 6, Integrated Project; 68 partner organisations). This experience will be of central importance and also guarantees a successful integration of LEGATO.

7.3.2 Decision-making structures and quality control

The LEGATO-PCC meets at least twice per year (video/email conferencing is possible). The PCC makes decisions, based on a simple majority, on all matters pertaining to the management of the project. In case of equal votes the coordinator’s vote is decisive. The PCC also decides on propositions to be voted on by the **General Assembly (GA)** (see below). In close cooperation with the Project Coordinator, the PCC is also responsible for the overall supervision of the scientific content and budget as well as the coordination of all activities carried out by the LEGATO partners within the various workpackages.

The composition of the **Steering Committee** is based on scientific tasks and areas of specialisation and ensures efficient management of the project. Research will be conducted within work packages, which will be headed by partners with long-term research experience in the relevant fields. Each work package (except of the coordination workpackage) will have a Steering Committee composed of the leaders of its sub-workpackages or tasks (see Table 7.2). Because of their multiple roles some consortium members are represented in more than one SC. Each Steering Committee will be represented by two delegates to the LEGATO-PCC (Table 7.2). All PCC delegates of the Steering Committees (SC) coordinate/streamline the activities of the project partners within their field of responsibility (strand or WP) and ensure that assigned scientific tasks and budget matters are effectively controlled.

The delegates of the SCs collect reports and other information generated within the workpackages and ensure that the respective partners fulfil their legal and contractual obligations towards the Commission and the other project partners. The reports must be submitted to the Project Coordinator at least 4 weeks before the deadline defined in the Consortium

Agreement. After the Coordinator and, where necessary, the PCC have checked their scientific content and legal implications, all these materials and documents are forwarded to the Commission. The PCC can refuse to accept documents if they do not meet the desired scientific quality or the legal requirements of the Commission or if they do not correspond to decisions previously made by the GA.

Table 7.2 Members of the LEGATO Steering Committees

Strand / WP Steering Committee	Members of Steering Committee
Strand 1 Nutrients & Production	Lead: Reinhold Jahn (MLU) & Ho Van Chien (MARD). Members: CABI: Keng-Yeang Lum; UGOE: Stefan Scheu; IEBR: Ha Quy Quynh; IRRI: N.N.; MARD: Ho Van Chien; MARDI: Mohd Norowi Hamid; OLANIS: Ralf Grabaum; UFZ: Doris Vetterlein.
Strand 2 Biocontrol & Pollination	Lead: Catrin Westphal (UGOE) & Gertrudo S. Arida (PhilRice) Members: UGOE: Teja Tscharntke, Stefan Vidal, Erwin Bergmeier; LUPO: Jürgen Ott; IRRI: KL Heong; MLU: Robin Moritz; UFZ: Markus Franzen, Ingolf Kühn, Josef Settele; TUM: Wolfgang W. Weisser, Manfred Türke.
Strand 3 Cultural Identity & Aesthetics	Lead: Susanne Stoll-Kleemann (UGR) & Monina Escalada (VSU); Members: CEPSTA: Dao Thanh Truong; IRRI: KL Heong; MARDI: Jamal Othman; S4you: Norbert Hirneisen; UFZ: Joachim Spangenberg, Christoph Görg, Karin Ulbrich.
WP 1 Multi-Stakeholder Analysis and Consultation	Lead: Joachim Spangenberg (UFZ) & Felix Müller (CAU); Members: all members of WP 1 (see Table 11.3; Chapt. 11.2).
WP 2 Driving Factors (field assessments)	Lead: Ingolf Kühn (UFZ) & Le Xuan Canh (IEBR); Members: all members of WP 2 (see Table 11.3; Chapt. 11.2).
WP 3 Driving Factors (experiments)	Lead: Roland Brandl (UMAR) & Dao Thanh Truong (CEPSTA); Members: all members of WP 3 (see Table 11.3; Chapt. 11.2).
WP 4 Integration	Lead: Kirsten Thonicke (PIK) & Joan Martinez Alier (UAB); Members: all members of WP 4 (see Table 11.3; Chapt. 11.2).
WP 5 Implementation	Lead: KL Heong (IRRI) & Mohd Norowi Hamid (MARDI; Malaysia); Members: all members of WP 5 (see Table 11.3; Chapt. 11.2).
WP 6 Dissemination	Lead: Lyubomir Penev (PENSOFT) & Norbert Hirneisen (S4Y); Members: all members of WP 6 (see Table 11.3; Chapt. 11.2).

To guarantee overall relevance, to facilitate implementation, to ensure scientific quality and to avoid getting lost in one's own world of thinking, the important link to stakeholders will be realized through WPs 1 and 5. Those stakeholders who are not LEGATO partners will become members of the LEGATO advisory board. Thus, envisaged for the board are representatives of national and international organisations, like:

- EC: DG ENVIRONMENT, DG ENVIRONMENT & DG AGRICULTURE ;
- EEA; ETCs;
- Scientific Working Group of the Habitats Committee;
- EPBRS;
- BirdLife International, IUCN-CEM, WWF, Oxfam, FAO;
- Re Assurance companies;
- Chemical companies;
- The international farm workers union (represented by IG BAU).

Furthermore, we believe in an **"automatic" control** mechanism within LEGATO, as all members in this consortium are highly motivated individuals who have successfully devoted their careers to understanding fundamental problems in environmental science, biodiversity research, ecology and/or socio-economic and policy research. In addition, the future careers of all depend greatly on maintaining a high output of innovative fundamental and applied environmental research that is published in the leading peer reviewed journals. This in itself provides additional "automatic" control of quality, guaranteed by the international review system.

The **General Assembly (GA)** is the highest decision-making body in the consortium and comprises all project partners, who are also eligible to vote on propositions presented to the GA. The GA takes decisions on the following:

- Expansion of the consortium or exclusion of partners from the consortium
- Premature end of the project
- Modifications of the Consortium Agreement
- All matters of fundamental importance to the consortium

A decision of the GA on the above matters (exceptions see below: "Changes to LEGATO consortium") requires that a two-third majority of the project partners vote in favour of a particular proposition. Each partner has one vote. Partners have to be in the project at the meeting date of the GA. Partners, which have left the project already or are not yet partners, have no vote. The GA also votes an **ombudsperson** that will be in charge of gender equity issues and general problems of human interactions within the project.

7.3.3 Changes to LEGATO consortium

The following mechanisms of changing the LEGATO consortium are envisaged:

- Unfunded participants can be added to the consortium, providing them with access to data and communication structures. The addition will involve the elaboration of a cooperation contract between the partner and the LEGATO coordinator. The contract will involve the unilateral acceptance by the added partner of all LEGATO code of conduct documents that may arise during the lifetime of the project and the commitment to an annual scientific progress report. The unfunded partner may, on his own costs, participate in all relevant LEGATO meetings but has no voting right in the LEGATO-GA. Failure to adhere to the rules agreed upon in the contract will lead to its termination (by decision of the LEGATO-PCC).
- Funded partners from the initial consortium can apply for termination of their consortium membership if an alternative solution for the timely delivery of their work can be ensured. Such decisions must be prepared in detail by the LEGATO-PCC and approved by the LEGATO-GA, unless the change is considered of minor importance by the LEGATO-PCC.
- The LEGATO-PCC can propose the termination of consortium membership for partners, who do not provide Deliverables in adequate quality and according to the time schedule of the project. The decision must be deliberated and prepared by the LEGATO-PCC in detail, considering all implications. The partner must be given adequate time to remedy the situation or to propose alternative solutions. The decision must be finally taken by the LEGATO-GA.
- Budget reallocations between partners can be made by the LEGATO-PCC directly if the change does not increase or reduce the annual allocation by more than 20% for each involved partner and all partners involved agree to the reallocation. Larger shifts require decisions by the LEGATO-GA (see above).

If unforeseen difficulties arise, a workpackage leader (including sub-WP leaders) will consult at the earliest possible time with all teams co-ordinated by him. Decisions will be made in the same way as within the Steering Committees. If there are implications beyond his co-ordination responsibility, he will also consult immediately with the SC head to raise the matter within the Steering Committee and/or consult the ombudsperson and the coordinator.

7.3.4 Management of knowledge

LEGATO adheres very strictly to the principles of free and open exchange of data and knowledge. All LEGATO results will be published in the freely available literature, as project reports, peer-reviewed journal papers, web material, or in other media. The LEGATO-SC monitors all aspects of dissemination and discusses a code of conduct to be agreed upon by the LEGATO-GA. The code of conduct will specifically ensure that project partners are appropriately acknowledged for material they provide to each other when publications are prepared – all partners will be requested to pay particular attention to this (through co-authorship or appropriate acknowledgement sections), including the acknowledgement of LEGATO as a project including its funding source. The Project Office together with the LEGATO coordinator/manager to be appointed will manage an intranet manuscript distribution system containing drafts of all relevant project documents, as well as external material that is needed for LEGATO members.

LEGATO will not produce commercial material, patents, or other legally restricted material.

The training and capacity building component (WP 7.3) is an important part of knowledge management, as it ensures that a broader community (incl. young scientists) gets exposed to and trained in concepts, theories, and methods developed by LEGATO partners.

7.3.5 Special cases

LUPO is an SME partner of the project for the utilisation of the project results. The other tasks related to LUPO will be performed within the UFZ activities of Jürgen Ott. Where appropriate, results of the project can be disseminated as joint activities of LUPO and UFZ.

S4Y and OLANIS have activities which are directly performed by them and others which will be done by colleagues employed under the umbrella of the UFZ. These differences are also indicated in the table of milestones (chapter 11.4; where the key responsibilities are always with the partner mentioned first).

8. Prospects of sustainable continued operation of the established structures after the end of funding

Prospects for continued operation exist in two respects: on the one hand, the research network established in the course of the project, and on the other hand the impacts on local agricultural practices.

Regarding the research network, all LEGATO investigators are committed to their vision of forging long-term research links between participating institutions, and in developing a self-sustaining research program. The coordinator’s vision of enhancing international academic collaborations, particularly in land use research, provides the necessary institutional commitment. This includes the long-term hosting of databases and maintenance of communication platforms. In addition sustainability will be sought by applications to national and international funding agencies for follow-on and implementation grants.

The sustainability of the Third Country institutions is evident from their long-term work in landscapes in SE Asia. Efforts (to understand and to intervene) that were commenced in these places have been sustained over periods extending up to a decade. The investigators are also committed to support students' career development, ensuring, in that sense as well, a long lasting scientific legacy.

For continued impacts on everyday practices, two factors are crucial: the demonstration and acknowledgement of benefits, and their institutionalisation. Regarding the former, field tests with ecological engineering in the Mekong delta have demonstrated the opportunities to reduce chemical inputs and the number of seedling while increasing the yields. Surprisingly, in farmers' language this was not described as reduced exposure to well-known health impacts from spraying or as economic gains, but rather as time surplus which was used for raising chicken: ecological engineering meant more chicken with the rice. Such simple, clear and down to earth messages can be spread through traditional exchange and learning systems, supported by the hands-on experience and the reflection process which is part of the training program in the socio-cultural experiments. Regarding institutionalisation, LEGATO will support the process by not only focussing on farmers, but – in collaboration with GLUES – by also presenting the results to the decision makers involved on several levels, and by publicity (press conferences or similar) in the respective administrative centres. A key contribution of the project consists of "translating" between different "languages of valuation": whereas "more chicken" may be the adequate and most appealing way of formulating potential project impacts for local farmers, for decision makers the language of economics is usually more appealing, pointing out macroeconomic benefits, cost saving, potential improvements of income levels and nutritional status, reduced vulnerability etc.

9. Participating partners from practice, science and industry as well as from third countries

A complete list of partners is provided right at the start of this document. LEGATO encompasses partners from practice, science and industry in order to achieve optimum results.

Practice and NGOs Particularly for extension and thus implementation of our results we have included partners from all regions: IRRI and PhilRice (Philippines), MARD (Vietnam), and MARDI (Malaysia). Stakeholders (and thus foreseen advisory board members) from practice are e.g. FAO, CERN and the EC-China biodiversity programme.

Science partners are German research institutes, incl. UFZ as coordinator and PIK, and German universities CAU, UGOE, MLU, UGR, TUM, and UMAR. Third country partners.

BIOSS and CKFF provide expertise for the continuity of already established project infrastructures. UAB participates for the valuation particularly in non-European societies. Particularly relevant is the inclusion of several mostly university based social science partners in LEGATO: CEPSTA (Vietnam), VSU (Philippines), UGR (D). Further science partners are also foreseen for the advisory board (e.g. to make their established transcontinental collaboration infrastructures available within LEGATO: Riccardo Bommarco of the Swedish Agricultural University SLU, Jacobus Biesmeijer and William Kunin of University of Leeds ULEEDS, and Simon G. Potts of the University of Reading UoR).

Business (incl. SME) partners are included for the establishment of online recording schemes (S4Y), GIS analysis as well as database work (OLANIS, CKFF), and landscape management and impact assessment (LUPO). Partner PENSOFT for Europe and partner CABI for Asia are foreseen for publication activities. Work with PENSOFT is based on very positive experiences in previous international projects which were closely linked to the LEGATO coordinator. Stakeholder contacts have been established to SwissRe (insurance of ESS e.g. within the Liability Directive), BASF (integrated pest management) and the International Farm Workers Union (social affairs, occupational health).

10. Finance structure (costs per workpackage) (not part of DoW)

11. Workpackage Structure and PM (personmonth) assignments

11.1 Workpackage Overview

The workpackage overview is presented in Table 11.1.

Table 11.1: LEGATO workpackage list and summary characteristics

WP No	WP title	Lead Partner	Start month	End month
1	**Multi-Stakeholder Analysis and Consultation**	UFZ (JSp)	2011 Mar	2015 Aug
1.1	Stakeholder Analysis & Stakeholder Board	UFZ (JSp)	2011 Mar	2015 Feb
1.2	Link to Coordination Project & Scenarios of Land use and Climate Change	PIK	2011 Mar	2015 Aug
2	**Driving Factors of ESF/ESS (field assessments)**	UFZ (IK)	2011 Mar	2015 Aug
2.0	Sites & Protocols	UFZ (IK)	2011 Mar	2014 Feb
2.1	Strand 1: Nutrients, Production & Water	MLU	2011 Sep	2015 Feb
2.2	Strand 2: Biocontrol & Pollination	IRRI	2011 Sep	2015 Feb
2.3	Strand 3: Cultural Identity & Aesthetics	UGR	2011 Sep	2015 Feb
2.4	Summary across Tasks	IEBR	2012 Sep	2015 Aug
3	**Driving Factors of ESF/ESS (experiments)**	UMAR	2011 Mar	2015 Aug
3.0	Sites & Protocols	UMAR	2011 Mar	2014 Feb
3.1	Strand 1: Nutrients, Production & Water	MLU	2011 Sep	2015 Feb
3.2	Strand 2: Biocontrol & Pollination	TUM	2011 Sep	2015 Feb
3.3	Strand 3: Cultural Identity & Aesthetics	UFZ (JSp)	2011 Sep	2015 Feb
3.4	Summary across Tasks	CEPSTA	2012 Sep	2015 Aug
4	**Integration (across ESF/ESS strands)**	PIK	2011 Sep	2015 Nov
4.1	Valuation	UAB	2011 Sep	2015 Nov
4.2	Indicators	CAU	2011 Sep	2015 Nov
4.3	Comprehensive ESS Assessment	CAU	2011 Sep	2015 Nov
4.4	Modelling	PIK	2011 Sep	2015 Nov

Table 11.1 (continued):

5	**Implementation**	IRRI	2013 Mar	2016 Feb
5.1	National & regional implementation (Policies & Data Provision from and to Stakeholders)	UFZ (JSp)	2013 Mar	2016 Feb
5.2	Landscape Level & Local Implementation (Ecol. Engin.)	IRRI	2013 Mar	2016 Feb
6	**Dissemination**	PENSOFT	2011 Mar	2016 Feb
6.1	Online Tools for active participation	UFZ (S4Y)	2011 Mar	2016 Feb
6.2	RAT (Risk Assessment Toolkit)	BIOSS	2011 Mar	2016 Feb
6.3	Publications, flyers & policy briefs	CABI	2011 Mar	2016 Feb
7	**Coordination**	UFZ	2011 Mar	2016 Feb
7.1	Scientific Coordination	UFZ	2011 Mar	2016 Feb
7.2	Management	UFZ	2011 Mar	2016 Feb
7.3	Training	IRRI	2011 Mar	2016 Feb

11.2 Financial and WP forms

The breakdown of finances in relation to the WPs of each partner organisation is not included in the DoW, while the WP involvement (quantified in PMs) of each LEGATO colleague is shown in the following table.

Table 11: LEGATO: individual employment in months per workpackage (WPs 1.1 – 3.4)

Name	Institution		WP 1.1	WP 1.2	WP 2.0	WP 2.1.1	WP 2.1.2	WP 2.1.3	WP 2.1.4	WP 2.2.1	WP 2.2.2	WP 2.2.3	WP 2.2.4	WP 2.3.1	WP 2.3.2	WP 2.3.3	WP 2.3.4	WP 2.4	WP 3.0	WP 3.1	WP 3.2	WP 3.3	WP 3.4
Settele (Spangenberg)	UFZ		3.0	2.0	1.0				2.0				2.0				2.0	2.0	2.0	1.0	1.0	1.0	4.5
Settele/Franzen (NN)	UFZ		3.0	2.0																			
Görg (NN)	UFZ																						
Auge/Schädler (NN)	UFZ																		2.0	5.0	8.0		2.0
Klotz/Durka (NN)	UFZ					6.0	3.0	3.0		1.0	2.0							2.0					
Kühn/Schweiger (NN)	UFZ				1.5		2.5			2.0	7.5	5.0	2.0		4.0			2.5					
Seppelt (NN)	UFZ																						
Vetterlein (NN)	UFZ				5.0	2.0	2.0	1.5	1.5										2.5	5.0			
Vetterlein (NN)	UFZ				3.0	4.0	2.0	1.5	2.5											5.0			
Müller (Burkhard)	CAU		2.5																				
Scheu (NN)	UGOE				1.0	3.5	2.5												1.0	5.0	5.0		
Tscharntke (Westphal)	UGOE				2.5					5.0	5.0	4.0	4.0					2.5					
Vidal (NN)	UGOE				1.0					2.0	4.0	2.5	2.0					1.5					
Bergmeier (NN)	UGOE						5.0			4.0	5.0	4.0											
Ott	UFZ/LUPO		1.0		1.0					2.0	5.0	2.0	2.0	2.0	4.0				2.0	2.0	2.0	2.0	2.0
Jahn (NN)	MLU					4.5	4.5	4.5	4.5										2.5	16.5			
Jahn (NN)	MLU				3.0	12.4	7.5	4.5	4.5										3.1	5.9			
Moritz (NN)	MLU				0.5					6.0	5.0	1.5	3.5										
Meyer (Grescho)	OLAN/UFZ				4.5	3.5				3.5				2.5				2.5					
Thonicke/Tietjen (NN)	PIK			14.0				2.0				2.0				2.0		3.0	2.0	2.0	2.0	2.0	2.0
Hirneisen (Harpke)	S4U/UFZ														5.0								
Stoll-Kleemann (Tekken)	UGR		5.0		1.0				7.5				3.5	1.0	1.0	1.0	17.5	5.0	1.0	1.0	1.0	3.0	1.0
Weisser (Türke)	TUM				3.0					7.0	10.0	5.0	5.0					6.0					
Brandl (Hotes)	UMAR																		1.5	15.0	16.5	15.0	5.0
Marion (NN)	BIOSS																						
Butler (NN)	BIOSS																						

Table 11 (cont.): LEGATO: individual employment in months per workpackage (WPs 1.1 – 3.4)

Name	Institution		WP 1.1	WP 1.2	WP 2.0	WP 2.1.1	WP 2.1.2	WP 2.1.3	WP 2.1.4	WP 2.2.1	WP 2.2.2	WP 2.2.3	WP 2.2.4	WP 2.3.1	WP 2.3.2	WP 2.3.3	WP 2.3.4	WP 2.4	WP 3.0	WP 3.1	WP 3.2	WP 3.3	WP 3.4
Kettle (NN)	BIOSS																						
Loke (NN)	CABI																						
Lum (NN)	CABI				1.0	4.0	2.0	2.0	2.0										1.0	5.0			
Truong (NN)	CEPSTA		2.0																			5.0	
Dam (NN)	CEPSTA																12.5						
Hoa (NN)	CEPSTA														7.5								
Tung (NN)	CEPSTA															5.0							
Chung (NN)	CEPSTA													7.5									
Ly (NN)	CEPSTA																	7.5					
Huong (NN)	CEPSTA																					5.0	1.0
Trang (NN)	CEPSTA																					5.0	
Kotarac (NN)	CKFF																						
Canh (NN)	IEBR		2.0		1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0					
Quynh (NN)	IEBR				2.5	5.0				5.0				5.0				5.0					
Sinh (NN soils)	IEBR				1.0	3.5	3.5	3.5	3.5										2.5	10.0			
Heong (NN)	IRRI		0.5		0.5				1.0	1.0	1.0	1.0								0.5	0.5		
Heong (NN)	IRRI		0.8		0.7				5.0	5.0	6.0	6.0								6.0	5.5		
Horgan (NN)	IRRI					0.7	0.5	0.5					5.0							0.3			
Horgan (NN)	IRRI		2.0		2.0	2.0	1.0	1.0	3.0	3.0	3.0	3.0	1.0							4.0	4.0		
Escalada (NN)	IRRI/VSU		2.0											2.0	3.0	2.0	3.0	1.0				3.0	3.0
Escalada (NN)	IRRI/VSU		2.0											4.0	4.0	4.0	5.0	3.0				7.0	5.0
Chien/Huan (NN)	IRRI/MARD		1.0		1.0	1.0	1.0	1.0	1.0	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0	1.0					
Norowi (NN)	MARDI		1.0		1.0					4.0	4.0	3.0	3.0					2.5			5.0		
Othman (NN)	MARDI																						
Penev/Stoev (NN)	PENSOFT																						
Georgiev	PENSOFT																						
Arida (NN)	PhilRice				0.5					1.0	1.0	1.0	1.0						3.0	6.0	6.0	6.5	10.0
Alier/Munda (NN)	UAB/ICTA		2.0													3.0							
Labajos (NN)	UAB/ICTA																						
TOTAL			**30**	**18**	**39**	**53**	**38**	**26**	**39**	**55**	**62**	**43**	**37**	**26**	**31**	**19**	**42**	**48**	**26**	**95**	**57**	**55**	**36**

Table 11 (cont.): LEGATO: individual employment in months per workpackage (WPs 4.1 – 7.3)

Name	WP 4.1	WP 4.2	WP 4.3	WP 4.4	WP 5.1	WP 5.2	WP 6.1	WP 6.2	WP 6.3	WP 7.1	WP 7.2	WP 7.3	PMs total
Settele (Spangenberg)	4.0	4.0	4.0		2.0	2.0			2.0	11.5	7.0		60
Settele/Franzen (NN)			5.0							10.0	10.0		30
Görg (NN)					6.0								6
Auge/Schädler (NN)									0.5			0.5	18
Klotz/Durka (NN)			1.0										18
Kühn/Schweiger (NN)			2.0									1.0	30
Seppelt (NN)		4.0	3.0	11.0									18
Vetterlein (NN)			2.0						1.5			1.0	24
Vetterlein (NN)													18
Müller (Burkhard)		37.5	6.0						1.0			1.0	48
Scheu (NN)													18
Tscharntke (Westphal)			1.0			2.5			2.5			1.0	30
Vidal (NN)						2.5			1.5			1.0	18
Bergmeier (NN)													18
Ott							3.0		3.0			1.0	36
Jahn (NN)													37
Jahn (NN)									5.0			1.0	47
Moritz (NN)									1.5				18
Meyer (Grescho)								41.5				2.0	60
Thonicke/Tietjen (NN)		5.0		19.0					1.0				58
Hirneisen (Harpke)					5.0	5.0	33.0						48
Stoll-Kleemann (Tekken)					5.0	3.5			1.0			1.0	60
Weisser (Türke)													36
Brandl (Hotes)			5.0						1.0			1.0	60
Marion (NN)								3.0					3.0
Butler (NN)								3.0					3.0
Kettle (NN)								3.0					3.0

Table 11 (cont.): LEGATO: individual employment in months per workpackage (WPs 4.1 – 7.3)

Name	WP 4.1	WP 4.2	WP 4.3	WP 4.4	WP 5.1	WP 5.2	WP 6.1	WP 6.2	WP 6.3	WP 7.1	WP 7.2	WP 7.3	PMs total
Loke (NN)					2.0	5.0	5.5	2.5	10.0	4.0		2.0	**31**
Lum (NN)													**17**
Truong (NN)													**7**
Dam (NN)													**12.5**
Hoa (NN)													**7.5**
Tung (NN)													**5**
Chung (NN)													**7.5**
Ly (NN)													**7.5**
Huong (NN)													**6**
Trang (NN)						2.0							**7**
Kotarac (NN)										3.0			**3**
Canh (NN)					5.0	14.0			1.0			2.0	**40**
Quynh (NN)			1.5	5.0				10.0				1.0	**40**
Sinh (NN soils)					1.0	1.5							**30**
Heong (NN)					1.0	0.5			0.5			1.0	**9**
Heong (NN)					5.0	0.5			0.8			0.7	**42**
Horgan (NN)													**7**
Horgan (NN)					4.0	1.0			2.0			2.0	**38**
Escalada (NN)					1.0	2.0							**22**
Escalada (NN)					2.0	2.0							**38**
Chien/Huan (NN)					5.0	14.0							**36**
Norowi (NN)					3.0	3.0			0.5				**30**
Othman (NN)					2.0	4.0							**6**
Penev/Stoev (NN)							6.0	6.0	24.0				**36**
Georgiev							4.0	4.0	4.0				**12**
Arida (NN)													**36**
Alier/Munda (NN)	5.0				2.5				0.5				**13**
Labajos (NN)	5.0												**5**
TOTAL	**14**	**51**	**31**	**35**	**52**	**65**	**52**	**73**	**65**	**29**	**17**	**20.2**	**1374**

11.3 Subcontractors List (without budget)

Applicant	Country	Project Coordinator/Partner	PMs
IRRI	Philippines	UFZ	96
IRRI (VSU)	Philippines	UFZ	60
IRRI (MARD)	Philippines (Vietnam)	UFZ	36
PhilRice	Philippines	UFZ	36
CABI	Malaysia	UFZ	48
MARDI	Malaysia	UFZ	36
IEBR/VAST	Vietnam	UFZ	110
CEPSTA	Vietnam	CAU	60
UAB/ICTA	Spain	CAU	18
PENSOFT	Bulgaria	MLU	48
BIOSS	UK	UFZ	9
CKFF	Slowenia	UFZ	3
amanu GmbH	Germany	UGR	n.a.
Univ. Kaiserslautern	Germany	UFZ (LUPO)	n.a.
GeoMobile GmbH	Germany	UFZ (S4Y)	n.a.
Adrian Landschafts-planung	Germany	UFZ (OLANIS)	n.a.
Terminal Consulting	Germany	UFZ (OLANIS)	n.a.
total			

11.4 List of LEGATO Milestones (Results & Products)

Milest. No	Milestone Name	WP No	Responsible Partner	Nature	Dissem. Level	Deliv. Month	Deliv. Date
1.1.1	Documentation, inventory of stakeholders	1.1	UFZ/CEPSTA	Report	Internal	3	2011 May
1.1.2	Information availability map, including data quality assessment	1.1	OLANIS/UFZ	Report	Internal	6	2011 Aug
1.1.3	Documentation of the result of initial stakeholder consultations	1.1	CEPSTA	Report	Internal	9	2011 Nov
1.1.4	Documentation of the stakeholder feedbacks concerning the prototype tests	1.1	UGR	Report	Internal	39	2014 May
1.2.1	List of data and scenario requirements of project partners, in particular those to be derived from local stakeholders	1.2	PIK	Report	Internal	10	2011 Dec
1.2.2	Report of regional evaluation of global data sets and locally available data from interviews back to GLUES	1.2	PIK	Report	Internal	12	2012 Feb
1.2.3	Report of specific needs on regional climate and land use change data in the best-case method for interpolation and model to be used, link to local experiences and available information	1.2	PIK/UFZ	Report	Internal	18	2012 Aug
1.2.4	Documentation of consistent climate and land use scenarios at the required spatial resolution for medium- and long-term projections provided for LEGATO from GLUES GDI	1.2	PIK	Report	Internal	24	2013 Feb
2.0.1	Series of project workshops with LEGATO partners and farmers, and reports on results.	2.0	UFZ/PhilRice/ MARD/IRRI/ IEBR/MARDI	Work-shop	Internal	2-6	2011 Apr - Aug
2.0.2	Draft document on data compilation and documentation (report) on contemporary and planned cropping strategies.	2.0	OLANIS	Report	Internal	12	2012 Feb
2.0.3	Report on assessed field nutrient (N,P,K) balance for selected fields in each ITS.	2.0	UFZ/MLU	Report	Internal	12	2012 Feb
2.0.4	Document and database/GIS layers on landscape structures for each ITS.	2.0	OLANIS	Report	Internal	30	2013 Aug
2.1.0	Document describing the relationship between Nutrient Cycles, Production & Water Provision with the suite of drivers used in LEGATO.	2.1	MLU/All WP Partners	Report	Public	48	2015 Feb
2.1.1.1	Final document compiling all maps and site descriptions regarding land-use.	2.1	OLANIS/IEBR	Report	Internal	12	2012 Feb
2.1.1.2	Soil profile description of dominant soil type at selected sites.	2.1	MLU/IEBR	Report	Internal	12	2012 Feb
2.1.1.3	Report of compiled information on nutrient availability, potential storage and turn-over.	2.1	MLU/IRRI	Report	Public	18	2012 Aug
2.1.2.1	Data on vascular plant species diversity per AoI will be available.	2.1	UGOE		Internal	18	2012 Aug
2.1.2.2	Manuscript on the composition, distribution and abundance of vascular plant species for each ITS.	2.1	UGOE	Report	Public	24	2013 Feb
2.1.2.3	Manuscript on diversity and abundance of functional groups of invertebrates (decomposers, predators, parasitoids, herbivores) and levels of herbivory by insect pest species on crop plants in the ITS.	2.1	UGOE	Report	Public	30	2013 Aug
2.1.2.4	Structural equation diagram of the relationships between elements of biodiversity, nutrients availability and agricultural production/land and water management.	2.1	UFZ	Report	?	48	2015 Feb
2.1.3.1	Model to relate the region, the change and the interaction between the environment factors and impacted systems will be available.	2.1	MLU/IEBR	Model	Internal	30	2013 Aug

2.1.4.1	Documentation of the perception of nutrient and water cycling and its link to production in the different farming communities, deciphering the cultural codes used to describe the links in the respective cultures (a precondition for the dissemination phase).	2.1	UFZ	Report	?	18	2012 Aug
2.1.4.2	Report on the impact of social structures, systems and hierarchies on production management and the way nutrient and water cycles are addressed is available.	2.1	UFZ	Report	Public	48	2015 Feb
2.2.0	Document describing the relationship between Biocontrol and Pollination with the suite of drivers used in LEGATO.	2.2	TUM/All WP Partners	Report	Public	48	2015 Feb
2.2.1.1	Review: Agricultural intensification, landscape structure, and water management and its effects on biocontrol agents in rice based agro-ecosystems.	2.2	IRRI	Report	Public	12	2012 Feb
2.2.1.2	Review: Agricultural intensification, landscape structure and the indicator role of pollinators for biocontrol agents in rice based agro-ecosystems.	2.2	IRRI/UGOE	Report	Public	12	2012 Feb
2.2.2.1	Report on the relationship between plant functional types and pollinator communities and functional structure will be available.	2.2	UFZ/UGOE	Report	Public	42	2014 Aug
2.2.2.2	Report on the relationship between alien and native plant species composition and diversity and diversity of pollinators and biocontrol organisms.	2.2	UGOE	Report	Public	45	2014 Nov
2.2.3.1	Model relating climatic covariates (incl. water provision) to pollinators and biocontrol systems will be available.	2.2	MLU	Model	Internal	36	2014 Feb
2.2.4.1	Draft document results for traditional farming practices of local inhabitants.	2.2	UGR	Report	Public	18	2012 Aug
2.2.4.2	Draft document impact of modern bee keeping on traditional bee keeping practices.	2.2	MLU	Report	Public	36	2014 Feb
2.2.4.3	Evaluation of traditional land and water management on pollination networks and biocontrol systems.	2.2	UGOE et al	Report	Public	45	2014 Nov
2.3.0	Document describing the relationship between Cultural Identity and Aesthetics with the suite of drivers used in LEGATO.	2.3	UGR/All WP partners	Report	Public	48	2015 Feb
2.3.1.1	Draft document on perceptions and non-monetary valuation of local stakeholders in aesthetics and local identity.	2.3	UFZ/UAB	Report	Public	30	2013 Aug
2.3.1.2	Voting system for stakeholder involvement in monitoring.	2.3	UGR/ IRRI (VSU)	Report	Public	48	2015 Feb
2.3.2.1	Draft document local perception of landscapes.	2.3	UGR	Report	Public	30	2013 Aug
2.3.2.2	Review: the role of local identity for preservation of biodiversity.	2.3	IRRI (VSU)/UFZ	Report	Public	48	2015 Feb
2.3.3.1	Report on climatic effects for architecture and touristic relevance.	2.3	S4Y	Report	Public	24	2013 Feb
2.3.4.1	Draft document influence of education level on local identity.	2.3	UGR	Report	Public	30	2013 Aug
2.3.4.2	Review: options (training activities) for education.	2.3	UGR	Report	Public	48	2015 Feb
2.4.1	Draft document describing the relationship between ecosystem services and land use (incl. water use).	2.4	UFZ	Report	Public	42	2014 Aug
2.4.2	Draft document describing the relationship between ecosystem services and biodiversity.	2.4	IRRI/UGOE	Report	Public	42	2014 Aug
2.4.3	Draft document describing the relationship between ecosystem services and climate.	2.4	PIK	Report	Public	42	2014 Aug
2.4.4	Draft document describing the relationship between ecosystem services and social systems.	2.4	CEPSTA	Report	Public	42	2014 Aug
2.4.5	Synthesis paper providing a conceptual framework for the relationship between land and water use, biodiversity, climate, social systems and ecosystem services.	2.4	TUM	Report	Public	54	2015 Aug

3.0.1	1st project workshop to agree on field experiments and the detailed protocols and their implementation on the different experimental sites.	3.0	UMAR	Work-shop	Internal	3	2011 May
3.0.2	Data provision to LEGATO partners (land and water use, inputs etc.)	3.0	UMAR	Report	Internal	9	2011 Nov
3.0.3	Presentation and final discussion on experimental designs and core elements of investigation in field trials in farmers' fields; preparatory work for implementation of experiments.	3.0	UMAR	Work-shop	Internal	12	2012 Feb
3.0.4	Final document on experimental designs and core elements of investigation in field and laboratory/greenhouse trials provided to all partners	3.0	UMAR	Report	Internal	15	2012 May
3.1.1.1	Experimental set-up of decomposition experiment along land (and water) use gradients	3.1.	UMAR	Experi-ment	Internal	12	2012 Feb
3.1.1.2	Selection of soil samples based on results of task 2 for investigations on Si-transformation	3.1.	UFZ/MLU	Experi-ment	Internal	19	2012 Sep
3.1.1.3	Selection of soil samples for investigation of phytolith (Si)-weathering	3.1.	UFZ/MLU	Experi-ment	Internal	26	2013 Apr
3.1.1.4	Set-up of experiment for investigation of phytolith (Si)-weathering	3.1	UFZ/MLU	Experi-ment	Internal	32	2013 Oct
3.1.1.5	Establishment of methods and experimental conditions for investigations on Si-transformation finished	3.1.	UFZ/MLU	Report	Internal	35	2014 Jan
3.1.1.6	Reports on process understanding for Si-transformation and availability for different soil types and impact of vegetation and water regime on Phytolith (Si)-weathering	3.1	UFZ/MLU	Report	Public	42	2014 Aug
3.1.2.1	Draft document on selection of sites for decomposition experiments in the ITS	3.1	UMAR/UGOE	Report	Internal	6	2011 Aug
3.1.2.2	Document on selection of model organisms for lab experiments with site and land (and water) use type specific decomposers to asses their specific contribution to ecologically and economically relevant ecosystem functions	3.1	UMAR/UGOE	Report	Internal	21	2012 Nov
3.1.2.3	Report and publication of the synthesis of soil biodiversity data and decomposition dynamics in the ITS depending on land use (incl. water management) traits. Set-up of functional experiments under controlled conditions on the effects of specific decomposer organisms	3.1	UMAR/UGOE/ UFZ	Report	Public	30	2013 Aug
3.1.3.1	Draft document on climate driven differences in the experimentally assessed dynamics of ESF/ESS related to nutrient cycling, water supply and production across and within study regions	3.1	UMAR/IRRI	Report	Public	36	2014 Feb
3.1.3.2	Draft document on the synthesis of results from M 3.1.3.1, region specific climate change scenarios and land use changes with suggestions for integration in concepts on sustainable land use	3.1	UMAR/IRRI	Report	Public	48	2015 Feb
3.1.4.1	Draft document on household selection and interview guidance	3.1	UFZ	Report	Internal	12	2012 Feb
3.1.4.2	First results on local knowledge concerning nutrient cycling, water management, productivity and related key species (list of indicators)	3.1	UFZ	Report	Public	36	2014 Feb
3.1.4.3	Draft document on local land and water management techniques in order to optimize productivity	3.1	MLU/UFZ	Report	Public	48	2015 Feb
3.2.1.1	Draft document on data on the relationship between nutritional status of crop plants and pest damage in relation to land use traits	3.2	UMAR	Report	Public	35	2014 Jan

3.2.1.2	Synthesis paper on recommendations relevant for practice and sustainable land use regarding economic and ecological benefits and risks of fertilization methods.	3.2	UMAR/UFZ	Report	Public	45	2014 Nov
3.2.2.1	Set-up of microcosm experiments on functional links between soil biodiversity and plant-herbivore interactions and set-up of field experiments for investigations of functional links between decomposers and natural biological control	3.2	UMAR/UGOE/ UFZ	Experiment	Internal	33	2013 Nov
3.2.2.2	Synthesis paper on the impact of land and water use intensity on functional links between soil biodiversity, productivity, biocontrol and plant-herbivore interactions in rice dominated crop systems.	3.2	UMAR/UGOE	Report	Public	48	2015 Feb
3.2.3.1	Draft document on climate driven differences in the impact of pest species on crop species and pollinator diversity in weed communities across and within study regions	3.2	UMAR	Report	Public	36	2014 Feb
3.2.3.2	Draft document on the synthesis of results from M 3.2.3.1, region specific climate change scenarios and land use and water supply changes with suggestions for integration in concepts on sustainable land use	3.2	UMAR/PIK	Report	Public	48	2015 Feb
3.2.4.1	Interview outcomes regarding biocontrol analysed and results documented	3.2	UFZ	Report	Internal	18	2012 Aug
3.2.4.2	Inventory of biocontrol-supporting established land use practices available	3.2	UFZ	Report	Public	36	2014 Feb
3.3.1.1	Draft document on social mapping and identities	3.3	UFZ et al	Report	Internal	12	2012 Feb
3.3.1.2	Social maps or card mosaics for the test sites	3.3	UFZ et al	Report	Internal	18	2012 Aug
3.3.1.3	Preliminary model on how land use and water management change impact local identity	3.3	UFZ et al	Model	Internal	36	2014 Feb
3.3.2.1	Using the collection of audio-visual material and the infrastructure the first social experiments as described above will be conducted.	3.3	UFZ et al	Experiment	Internal	15	2012 May
3.3.2.2	Draft document on the relevance of biodiversity for local identities in the test regions	3.3	UFZ et al	Report	Public	30	2013 Aug
3.3.4.1	Draft document on locally perceived ESS and their relative importance	3.3	UFZ et al	Report	Public	12	2012 Feb
3.3.4.2	Draft document on the service providing units SPUs of socio-cultural and socio-economic services, as perceived by the service beneficiaries, and their potential links to provisioning and regulating services	3.3	UFZ et al	Report	Public	15	2012 May
3.3.4.3	Document on the specific social structures behind land use patterns, and their change with modernisation, urbanisation and migration, assessing also the feedback of these changes on the dynamics of land use change	3.3	UFZ et al	Report	Public	24	2013 Feb
3.3.4.4	Qualitative assessment of future social structure changes under climate change scenarios, and their impact on local dynamics and land use and water level change	3.3	UFZ et al	Report	Public	36	2014 Feb
3.3.4.5	Monitoring and evaluation of the socio-structural and economic impacts of the social learning experiments	3.3	UFZ et al	Report	Public	54	2015 Aug
3.4.1	Draft document on recommendations for the implementation functional ecological indicators for region specific land use strategies, water management and sustainable land use.	3.4	UMAR	Report	Public	48	2015 Feb
3.4.2	Draft document on concepts for the integration of results on the land use-biodiversity-ESF/ESS relationship in knowledge and decision making of local farmers and administration	3.4	UMAR	Report	Public	50	2015 Apr

3.4.3	Synthesis paper on a socio-economic view on biodiversity-ESF/ESS relationships in the different study regions in Europe and Asia and impacts of land use and water management change and climate change scenarios	3.4	UMAR/UFZ	Report	Public	52	2015 June
4.1.1	Draft inventory of values related to landscape and land (and water) use structures and patterns	4.1	UFZ et al	Report	Internal	12	2012 Feb
4.1.2	Draft document on the monetary and non-monetary value of the ESS analysed in LEGATO	4.1	UAB	Report	Internal	24	2013 Feb
4.1.3	Preliminary estimate of the cost of inaction	4.1	UFZ	Report	Internal	36	2014 Feb
4.1.4	Economic balance of ecological engineering (assessing costs and gains, in terms of money, time (as far as data permit) and social change	4.1	IRRI (VSU)	Report	Public	54	2015 Aug
4.2.1	Literature review on applied indicator frameworks	4.2	CAU	Report	Public	10	2011 Dec
4.2.2	Report on conceptual guidelines after stakeholder and partner consultations	4.2	CAU	Report	Internal	10	2011 Dec
4.2.3	Report on the qualitative assessment of integrity and ecosystem services (Hypothesis paper and maps)	4.2	PIK	Report	Internal	12	2012 Feb
4.2.4	Strategy paper on indicator-model-linkages (with WP 4.4)	4.2	PIK/CAU	Report	Internal	15	2012 May
4.2.5	Literature review on applied resilience and adaptability concepts	4.2	PIK	Report	Public	16	2012 June
4.2.6	Documentation of the key indicator set proposal	4.2	CAU	Report	Internal	16	2012 June
4.2.7	Preliminary report on the draft indicator framework	4.2	CAU	Report	Internal	24	2013 Feb
4.2.8	Documentation of indicator scale matrices	4.2	CAU	Report	Internal	18	2012 Aug
4.2.9	Workshop on results for ESS & integrity indicators	4.2	CAU	Worksh.	Internal	28	2013 June
4.2.10	Workshop on results for DPSIR components	4.2	UFZ	Workshop	Internal	33	2013 Nov
4.2.11	Report on the developed indicator framework concept and prototype	4.2	CAU	Report	Internal	36	2014 Feb
4.2.12	Documentation of scenario calculation results (Resilience and adaptability of LEGATO indicators)	4.2	PIK	Report	Internal	42	2014 Aug
4.2.13	Documentation on ecological engineering results	4.2	UFZ	Report	Internal	44	2014 Oct
4.2.14	Technical implementation in RAT and online toolkit	4.2	OLANIS/UFZ	Onl. tool	Public	44	2014 Oct
4.2.15	Documentation of concepts, tools and results incl. indicator fact sheets	4.2	CAU	Report	Public	48	2015 Feb
4.3.1	Comparative documentation of the human-environmental interaction types in the case study areas on the basis of data gathered earlier WPs, using the CBD/IUCN ecosystem management principles	4.3	PIK	Report	Public	24	2013 Feb
4.3.2	Workshop on response functions between the elements of the model components Pressure – State and Impact – Human well-being	4.3	PIK	Workshop	Internal	36	2014 Feb
4.3.3	Joint scientific paper on ecosystem service footprints/HANPP analysis	4.3	PIK	Report	Public	48	2015 Feb
4.4.1	Agreement with stakeholders and local experts on feedbacks between surrounding landscape and agricultural systems	4.4	PIK	Report	Internal	40	2014 June
4.4.2	Summary of feedbacks between surrounding landscape and agricultural systems which will be considered in modeling framework	4.4	PIK	Report	Public	42	2014 Aug
4.4.3	Results of Water budget modelling based on WASMOD	4.4	CAU	Report	Public	46	2014 Dec
4.4.4	Implementation of feedbacks in LPJmL and analysis of the role of feedback mechanisms for agricultural production (incl. water provision)	4.4	PIK	Other	Internal	46	2014 Dec

4.4.5	Analysis of the impacts of land use intensification, biodiversity, and climate across scales	4.4	UFZ	Report	Internal	46	2014 Dec
4.4.6	Documentation of impacts of land use intensification, biodiversity, and climate across scales	4.4	UFZ	Report	Public	48	2015 Feb
4.4.7	Analysis of the impacts climate change and potential buffer mechanisms of the surrounding landscape on agricultural production	4.4	PIK	Report	Internal	54	2015 Aug
4.4.8	Documentation of impacts climate change and potential buffer mechanisms of the surrounding landscape on agricultural production	4.4	PIK	Report	Public	56	2015 Oct
5.1.1	Draft document: Recommendations for agricultural practices for sustainable management	5.1	UFZ	Report	Internal	35	2014 Jan
5.1.2	Draft manual: analytical framework and tools for assessing impact of agricultural (incl. water managem.) practices & CC on rice based ecosystems	5.1	IRRI	Report	Internal	36	2014 Feb
5.1.3	Report on farmers' KAP in conservation practices	5.1	CAU	Report	Internal	12	2012 Feb
5.1.4	Report on farmers' evaluation of key conservation practices	5.1	CAU	Report	Public	30	2013 Aug
5.1.5	Report on policies related to conservation and agriculture in the pilot sites	5.1	CAU	Report	Public	36	2014 Feb
5.1.6	Report on the policy dialogues conducted in key implementation sites.	5.1	CAU	Report	Public	36	2014 Feb
5.2.1	Draft document on impact of agricultural (incl. water management) practices and climate on biodiversity and ecosystem services in key sites	5.2	IRRI	Report	Internal	36	2014 Feb
5.2.2	Report on implementation of ecological engineering strategies showing the degree of already achieved implementation	5.2	IRRI	Report	Public	48	2015 Feb
5.2.3	Report on prospects of ecological engineering as baseline for extension services.	5.2	IRRI	Report	Public	60	2016 Feb
6.1.1.1	Setting up IT infrastructure.	6.1	UFZ (S4Y)	Online tool	Internal	6	2011 Aug
6.1.1.2	Launch prototype of online community interface.	6.1	S4Y/UFZ	Online tool	Public	12	2012 Feb
6.1.1.3	Launch final version of online community interface.	6.1	S4Y/UFZ	Online tool	Public	24	2013 Feb
6.1.1.4	Webservice for handling observation data via mobile devices.	6.1	S4Y/UFZ	Online tool	Public	30	2013 Aug
6.1.1.5	Integration of other biodiversity data sources.	6.1	S4Y/UFZ	Data	Public	42	2014 Aug
6.1.1.6	Interfaces and data mining for other project partners.	6.1	UFZ (S4Y)	Online tool	Public	48	2015 Feb
6.1.1.7	Report on IT infrastructure.	6.1	UFZ (S4Y)	Report	Public	60	2016 Feb
6.1.2.1	Draft of preliminary species list will be available.	6.1	S4Y/UFZ (LUPO)	Data	Internal	6	2011 Aug
6.1.2.2	Compilation of preliminary species list.	6.1	S4Y/UFZ (LUPO)	Data	Public	12	2012 Feb
6.1.2.3	Species fact sheets.	6.1	PENSOFT	Report	Public	18	2012 Aug
6.1.2.4	Identific. aids for dragonflies online, print, iPhone.	6.1	S4Y/UFZ (LUPO)	Complex	Public	24	2013 Feb
6.1.2.5	Identification aids for Android.	6.1	UFZ (S4Y)	Online tool	Public	30	2013 Aug
6.1.2.6	Revision of selected species list.	6.1	S4Y	Data	Public	36	2014 Feb
6.1.1.7	Report on identification aids for citizen scientist involvement.	6.1	S4Y	Report	Public	60	2016 Feb
6.1.3.1	Draft for PR campaign.	6.1	S4Y/UFZ	Report	Internal	6	2011 Aug
6.1.3.2	Launch of campaigns in the AoI.	6.1	PENSOFT	Complex	Public	24	2013 Feb
6.1.3.3	Launch of campaigns in the AoI.	6.1	PENSOFT	Complex	Public	36	2014 Feb
6.1.3.4	Launch of campaigns in the AoI.	6.1	PENSOFT	Complex	Public	48	2015 Feb

6.1.3.5	Report on PR campaigns for citizen science.	6.1	S4Y/UFZ	Report	Public	60	2016 Feb
6.2.1	Report describing characterisation/categorisation of expected project result types and definition of a suitable database structure for the web-based Ecosystem services RAT.	6.2	BIOSS/OLANIS/UFZ	Report	Internal	12	2012 Feb
6.2.2	Identify opportunities for mathematical modelling or statistical analysis and develop collaborative projects as appropriate, e.g., bio-control of crop pests in heterogeneous landscapes; the design and analysis of experimental studies; or on the relationship between biodiversity and ESF/ESS.	6.2	BIOSS	Report	Internal	12	2012 Feb
6.2.3	ER model and implementation of database and development of suitable tools for data upload	6.2	UFZ (OLANIS)	Complex	Internal	24	2013 Feb
6.2.4	Report detailing preliminary project results to be included in M 6.2.3.	6.2	BIOSS	Report	Internal	30	2013 Aug
6.2.5	Review opportunities for the development of mathematical models and statistical analysis within the consortium & initiate further projects as appropriate.	6.2	BIOSS	Report	Internal	36	2014 Feb
6.2.6	Populate prototype web-based RAT with search & visualisation tools (e.g., map server) including preliminary project results,	6.2	PENSOFT/ UFZ (OLANIS)	Online tool	Internal	36	2014 Feb
6.2.7	Prototype web-based RAT including preliminary project results.	6.2	UFZ (OLANIS)/ PENSOFT	Online tool	Public	36	2014 Feb
6.2.8	Stake-holder test and report collating feedback on both results and software tool.	6.2	BIOSS/UFZ	Report	Internal	42	2014 Aug
6.2.9	Refine prototype RAT: search and visualisation tools	6.2	OLANIS	Online tool	Public	48	2015 Feb
6.2.10	Report describing the web-based RAT including final representative project results.	6.2	BIOSS	Report	Public	60	2016 Feb
6.2.11	Web-based RAT including final representative project results available.	6.2	BIOSS/OLANIS	Online tool	Public	60	2016 Feb
6.3.1	Web conference for agreement on the General Communication Strategy and project logo	6.3	PENSOFT	Other	Internal	1	2011 Mar
6.3.2	Public workshop	6.3	UFZ	Workshop	Public	4	2011 June
6.3.3	Elaboration of General Communication Strategy report	6.3	PENSOFT	Report	Internal	4	2011 June
6.3.4	Logo, brochures/flyers (for the general public and interested scientists)	6.3	PENSOFT	Report	Public	3	2011 May
6.3.5	Website open to the public which describes project concepts, setup and progress	6.3	PENSOFT	Online toll	Public	4	2011 June
6.3.6	Discussion of planned publications (books, guidelines)	6.3	PENSOFT	Report	Internal	12	2012 Feb
6.3.7	Scientific workshop	6.3	UFZ	Workshop	UFZ	12	2012 Feb
6.3.8	Publication and dissemination of results via brochures/books (e.g. multilingual manuals/guidelines for e.g. best land-use practices in the project countries; models describing the relationship between land use characteristics, biodiversity and ecosystem services; etc.)	6.3	PENSOFT	Report	Public	18	2012 Aug
6.3.9	Several publications in both popular and scientific media (e.g., BioRisk journal)	6.3	PENSOFT	Report	Public	20	2012 Oct
6.3.10	Publication of policy briefs for project results	6.3	PENSOFT	Report	Public	36	2014 Feb
6.3.11	Publication of indicator brochure for stakeholders and managers	6.3	PENSOFT	Report	Public	44	2014 Oct
6.3.12	Information flyers for ecological engineering, RAT and/or online tool applications)	6.3	PENSOFT	Report	Public	48	2015 Feb

6.3.13	Production of a series of scientific publications in fundamental and applied journals which integrate models and experiments towards the goal of a biodiversity conservation programme on the one and a standardised approach for Environmental Impact Assessment on the other hand	6.3	PENSOFT	Report	Public	1-60	Throughout LEGATO
7.1.1	Developing a communication strategy and setting up the necessary infrastructure, including access to existing regular electronic newsletters, the electronic open communication platform.	7.1	UFZ	Complex	Internal	3	2011 May
7.1.2	Establishment of the advisory board	7.1	UFZ	Other	Public	6	2011 Aug
7.1.3	Scientific papers, conference presentation and proceedings, booklet(s), books, CD-ROMs (whatever is appropriate)	7.1	UFZ	Other	Public	1-60	Throughout LEGATO
7.1.4	PCC meetings	7.1	UFZ	Other	Internal	½ yearly	½ yearly
7.2.1	1st report to the DLR/BMBF.	7.2	UFZ	Report	Internal	12	2012 Feb
7.2.2	2nd report to the DLR/BMBF.	7.2	UFZ	Report	Internal	24	2013 Feb
7.2.3	3rd report to the DLR/BMBF.	7.2	UFZ	Report	Internal	36	2014 Feb
7.2.4	4th report to the DLR/BMBF.	7.2	UFZ	Report	Internal	48	2015 Feb
7.2.5	5th report to the DLR/BMBF.	7.2	UFZ	Report	Public	60	2016 Feb
7.2.6	1st GA meeting.	7.2	UFZ	Meeting	Internal	3	2011 May
7.2.7	2nd GA meeting.	7.2	UFZ	Meeting	Internal	12	2012 Feb
7.2.8	3rd GA meeting.	7.2	UFZ	Meeting	Internal	24	2013 Feb
7.2.9	4th GA meeting.	7.2	UFZ	Meeting	Internal	36	2014 Feb
7.2.10	5th GA meeting.	7.2	UFZ	Meeting	Internal	48	2015 Feb
7.2.11	6th GA meeting.	7.2	UFZ	Meeting	Internal	60	2016 Feb
7.2.12	List(s) of published outputs of project; in particular scientific and non-scientific paper contributions (newspapers, scientific papers).	7.2	UFZ	Report	Public	1-60	Throughout LEGATO
7.3.1	Introductory course “Statistics for Ecologists”.	7.3	UFZ	Workshop	Internal	12	2012 Feb
7.3.2	GIS and database management training course.	7.3	OLANIS/UFZ	Workshop	Internal	18	2012 Aug
7.3.3	Advanced course “Statistics for Ecologists”.	7.3	UFZ	Workshop	Internal	24	2013 Feb
7.3.4	Training workshops for citizen scientists.	7.3	IRRI	Workshop	Public	30	2013 Aug
7.3.5	Successful completion of GIS workshop, resulting in increased skills and experience.	7.3	OLANIS/UFZ	Workshop	Internal	36	2014 Feb
7.3.6	Indicator framework course.	7.3	CAU	Workshop	Public	45	2014 Nov

12. Workpackage Descriptions

12.1 WP 1: Multi-Stakeholder Analysis and Consultation

Overall responsibility of WP 1: Joachim Spangenberg (UFZ) in close cooperation with Felix Müller (CAU) and the Asian research partners

General aims of the WP: interaction with stakeholders and linking with the coordination project

Work package number	**1.1**	**Stakeholder Analysis & Stakeholder Board**				Start: 2011 March	
Partner	UFZ	UGR	IRRI (VSU)	IRRI	CAU	CEPSTA	
Personmonths (PM)	6	5	4	3.3	2.5	2	
Partner	UAB/ ICTA	IEBR	UFZ (LUPO)	IRRI (MARD)	MARDI		TOTAL
Personmonths (PM)	2	2	1	1	1		30

Objectives

- To identify the relevant local and regional stakeholders (administrators, farmers, community representatives) and involve them into the project (discussion partners, participants in discourses, stakeholder board members).
- To identify information sources for objective (quantitative) and subjective (qualitative) information on service consumption, valuation and the perceived links to biodiversity and land use changes.
- To use stakeholder's problem perceptions to adapt the indicator system to the local situation, thus ensuring its meaningful applicability.
- To maintain stakeholder participation in the indicator testing and refining process.

Description of work

Stakeholders can be local decision makers, government representatives, members of important families, representatives of specific cultural or economic groups, farming communities, individual farmers, etc. The composition of relevant stakeholders will differ from site to site. To ensure adequate information access and even more so effective implementation, the right choice of stakeholders to be involved is critical.

Reliable data sources are a precondition for change analysis, in the bio-chemical and ecological domains (e.g. land use patterns, pesticide use, etc.) as much as in the socio-cultural one (values attached, preferences, etc). They are also crucial for social structure analysis (ownership patterns, power structures,...). Identifying such sources is a challenge not to be underestimated.

As a part of the pre-test of the field site information collection of LEGATO, the representative stakeholders identified in 1.1.N.1 will be interviewed to find out the focal elements, processes and problems which they want to see included within the indicator system. Also the structure, the mode of operation and the layout of the indicator framework will be discussed. The results of these consultations will contribute to the applied layout of the indicator framework.

During the final project phase the resulting indicator framework will be tested by the local LEGATO partners, involving where possible the stakeholder group. The resulting advices will be guidelines for the final production of the indicator framework.

Milestones (Results & Products)

- **M 1.1.1 (2011 May):** Documentation, inventory of stakeholders
- **M 1.1.2 (2011 Aug):** Information availability map, including data quality assessment
- **M 1.1.3 (2011 Nov):** Documentation of the result of initial stakeholder consultations
- **M 1.1.4 (2014 May):** Documentation of the stakeholder feedbacks concerning the prototype tests

Work package number	**1.2**	**Link to Coordination Project & Scenarios of Land use and Climate Change**				Start: 2011 March
Partner	PIK	UFZ				TOTAL
Personmonths (PM)	14	4				18

Objectives

- To collect empirical evidence of climate change symptoms, or climate-change alike phenomena, in the pilot areas, as the empirical basis for stakeholder discussions about climate risks; to discuss this local experience and the LEGATO scenarios, in particular risk perception and the perceived need for adaptation, and the options available (with ecological engineering one possible option) with local representatives and collect their reactions, past efforts and proposed future adaptation strategies.
- To discuss scenario and data requirements at different spatial scales for medium- and long-term projections with LEGATO partners and to communicate specific data and scenario requirements to the coordination project GLUES, specifically the GLUES GDI partner.
- To evaluate global climate and land use scenarios using stakeholder dialogue results from WP 1.1 to allow for generating adequate regional-scale pattern in Germany and South/South-East Asia.
- To work in close collaboration with groups in GLUES on methods, parameterisation and simulations for regionalisation of climate and land use change scenarios
- To provide all work packages with consistent climate and land use scenarios

Description of Work

This WP will coordinate the scenario and data requirements of LEGATO partners, concerning climate and land-use changes, as well as data needs for land surface, water resources and use, agriculture, and biodiversity. These requirements include historical, present and future data. The coordination will be done through discussions with other work packages (particularly WP 2 and 3). These will also help to collect empirical evidence for climate change symptoms, or climate-change like phenomena, in the pilot areas, as the empirical basis for stakeholder discussions about climate risks. In this context, a challenge will be the acquisition of data in an adequate spatial resolution (i.e. spatially explicit data at the sub-regional level if required by project partners) and the integration of data from modelling, measurement and oral reporting. Stakeholder interviews will be a valuable source of information not only on past events and their perception, but also on the willingness to adapt, which in turn is important not only for the later implementation and adaptation, but also for the scenario development.

As a first step, the coordination project GLUES will build a geodata infrastructure (GLUES GDI) for global data. In close collaboration with climate and land use experts of WP2 and 3 in GLUES, regional-specific requirements, which evolved in the stakeholder dialogue and expert questionnaire in WP2 and 3 of LEGATO, will be communicated to the GLUES GDI. This allows for evaluating suitable regionalization methods and models to be used to interpolate global climate and land use change scenarios to the regional scale and at the same time generating a consistent disaggregation of global data. We will work in close collaboration with the GLUES scenario groups on the regionalization of climate and land use scenarios to evaluate best-case parameterisation, methods and simulation experiments. The resulting harmonized regional data sets and region-specific solutions will then be communicated back to the LEGATO partners which ensure the transparency of the data sets. In addition, the scenarios will be presented to local representatives and their reactions, past efforts and proposed future adaptation strategies will be collected.

The region-specific evaluation of global land use scenarios, in particular, will help to improve land use modeling at the global scale. As an iterative process, all findings of project partners that are relevant within the coordination project are communicated to GLUES. As GLUES also regards this as an iterative process between the Coordination project and the regional projects this advances the global analysis and associated scenarios.

Milestones (Results & Products)

- **M 1.2.1 (2011 Dec):** List of data and scenario requirements of project partners, in particular those to be derived from local stakeholder
- **M 1.2.2 (2012 Feb):** Report of regional evaluation of global data sets and locally available data from interviews back to GLUES
- **M 1.2.3 (2012 Aug):** Report of specific needs on regional climate and land use change data in the best-case method for interpolation and model to be used, link to local experiences and available information
- **M 1.2.4 (2013 Feb):** Documentation of consistent climate and land use scenarios at the required spatial resolution for medium- and long-term projections provided for LEGATO from GLUES GDI

12.2 WP 2: Driving Factors of ESF/ESS (field assessments)

Overall responsibility of WP 2: Ingolf Kühn (UFZ) in close cooperation with Le Xuan Canh (IEBR; Vietnam)

General aims of the WP: In a gradient of predominantly agriculturally used sites (see Table 6.1) assessments of the impacts of different pressures (land use, water management, climate, economic situation and social system) and biodiversity on the LEGATO ESF/ESS strands are analysed via correlative approaches in rice based landscapes. Baseline data have to be compiled and/or collected in close cooperation with agricultural and other research and extension institutions. New data are to be compiled in cooperation with local farmers and authorities and in close coordination among the different LEGATO partners.

Work package number	**2.0**	**Sites & Protocols**				Start: 2011 March	
Partner	UFZ	UGOE	OLANIS	IEBR	MLU	IRRI	TUM
Personmonths (PM)	10.5	4.5	4.5	4.5	3.5	3.2	3
Partner	UGR	CABI	MARDI	UFZ (LUPO)	MARD	PhilRice	TOTAL
Personmonths (PM)	1	1	1	1	1	0.5	39

Objectives

- To select appropriate rice dominated research sites of different land use and water management intensity and suitable socio-cultural and economic characteristics, including conventional farming and ecological engineering within the pre-selected LEGATO AoIs in both structurally poor and rich landscape settings (all WP partners).
- To agree on compilations of baseline life science and socio-cultural data on AoIs, ITS, and ETS.
- To assess measures of landscape structures (landscape metrics).
- To identify a site specific balance of major plant nutrients (N, P, K) based on interviews with farmers and local authorities.
- To cluster the socio-economic structures found to enhance comparability
- To finally agree on standard protocols for life science and socio-cultural experiments.
- To make these data available to the LEGATO consortium.

Description of work

We will establish a network of farmers and farming enterprises (while using existing working groups/cooperatives etc.) in the AoI for an intensive data compilation and documentation on contemporary and planned cropping strategies. Data mining on social and economic conditions, agricultural land use, field structure etc. will be performed as basis to assess the present conditions of biodiversity, ESF and ESS. This information will be delivered to all LEGATO partners involved in WP 2 & 3.

Collation of baseline data will at least include land ownership, subsistence levels, land use, percentage cover of different crops, agricultural practices (fertiliser use, water management, plant protection, crop rotation etc.), yields, nutrient contents in soils, in surface and ground water. We will assess a larger set of landscape structure measures, which will include land use identity (land use classes), size of specific land-uses, selected landscape metrics (e.g., patch numbers, length of margins, size of woodlands, hedgerows or other greenveining structures). These serve as a bases to be related statistically to a large number of parameters assessed within LEGATO by advanced methods (e.g., considering spatial and temporal relationships).

We will contribute to the questionnaire for farmers which will be interviewed (cf. WP 3.3) in the framework of LEGATO. Questions will be worked out, which refer to site specific yield and use of crop residues and inputs (manure, compost, waste water, mineral fertilizer etc.), in order to establish a balance for N, P and K.
The collated data will be made available through an internal web-based project document and data repository.

Milestones (Results & Products)
M 2.0.1 (2011 Apr-Aug): Series of project workshops with LEGATO partners and farmers, and reports on results, which includes

A) agreements on detailed research sites within the different Areas of Investigation AoI,
B) documentation of the discussion on information requirements and availability, and
C) agreements on data transfer and treatment.

M 2.0.2 (2012 Feb): Draft document on data compilation and documentation (report) on contemporary and planned cropping strategies, and their motivations.
M 2.0.3 (2012 Feb): Report on assessed field nutrient (N,P,K) balance for selected fields in each ITS.
M 2.0.4 (2013 Aug): Document and database/GIS layers on landscape structures for each ITS.

Work package number	**2.1**	**Strand 1: Nutrients, Production & Water Provision**				Start: 2011 Sep	
Partner	MLU	UFZ	IEBR	IRRI	UGOE	CABI	
Personmonths (PM)	47	34	23	15	11	10	
Partner	UGR	IRRI (MARD)	OLANIS	PIK			TOTAL
Personmonths (PM)	8	4	4	2			156

Objectives

- To assess the relationship between Nutrient Cycles, Production & Water Provision with the suite of drivers used in LEGATO.

Task 2.1.1: Land Use Impacts on Nutrient Cycles, Production & Water Provision

- To provide background information on topology and soil types and their spatial association within a region and relate this information to land and water use, in particular rice production system of the area including complementary vegetable production.

- To describe in detail representative soil profiles for selected sites, to provide in depth information on (trends in) nutrient availability, water holding and sorption capacity and ongoing soil forming processes.
- To obtain information on the nutritional and water status of the crop during the cropping season, with a focus on elements of particular relevance for growth and biocontrol, i.e., N and Si.

Task 2.1.2: Biodiversity Relevance for Nutrient Cycles, Production & Water Provision

- To assess the relationship between plant species diversity and productivity / nutrient cycling. Data will be used to establish a system of biotic indicators for land and water use changes and (in combination with results of WP3) environmental performance indicators (EEF/EES). The indicators will also serve as input for the indicator development process in WP 4.
- To assess the importance of land and water use caused changes in biodiversity of decomposers for the cycling of organic matter and nutrients (data provision for experiments in WP3).
- To provide information on nutrient status of sites adjacent to field sites, covered by vegetation which interacts with the field site (source of organic manure, sink for excess fertilizer application, habitat for organisms related to biocontrol, source of weed or pest propagules).

Task 2.1.3: Climatic Effects on Nutrient Cycles, Production & Water Provision

- To assess the impact of weather, climate and climate change on nutrient cycling and water provision.
- To assess the impact of bio-climate (using WorldClim) and climate change on the distribution of biomass and fluxes.

Task 2.1.4: Effects of the Social System on Nutrient Cycles, Production & Water Provision

- To assess how the social and economic structure of land and water use (ownership patterns, stratification, management as private, public or common pool resource, export orientation, migration, demographic change) affect production patterns and priorities, for instance the access to inputs, with subsequent influence on nutrient cycling.
- To assess which service providing units SPU are identified by local residents as providing the provisioning service of crop production, if water provision and/or nutrient cycling is recognised as such an SPU, or as a (regulating) service in its own right, and how managing this service is culturally coded.

Description of work

Task 2.1.1: Land Use Impacts on Nutrient Cycles, Production & Water Provision

At the scale of AoI information on geology, topography, spatial distribution of soil units and soil data will be derived from literature and available databases (ICSU World Data Centre for Soils, locally available maps and soil data, information of local public authorities). Wherever possible more detailed information will be collected from local institutions and residents. A number of both are involved in LEGATO as stakeholders. Further information which will be provided are: soil maps for each ITS region including a description of the main properties of the dominant soil types and the relevance of these properties in relation to the land use system under consideration, i.e. water provision and storage capacity, vulnerability to erosion, likelihood of leaching, etc.; the selection of ITS, agreement about precise location within the consortium; the evaluation of available maps and databases, the decision about spatial resolution of the maps for each region, the interpretation of maps according to needs of members of consortium including stakeholders. A database of environment factors of the regions will be designed and provided.

Within the regions up to two sites will be selected for detailed investigation of representative soil profiles for rice production. Selection of sites will be coordinated with the partners of LEGATO. The profile description also serves as verification of the information used for compilation of soil maps. Profiles will be described in the field and samples from different horizons will be collected for analyses of chemical and physical soil properties (Nmin, available P, K, pH, CEC, amorphous and crystalline Fe-(hydr)oxides, C_{org}, C/N ratio, texture, bulk density). Sampling of water in and outputs as well as extraction of soil solution and measurement of nutrients will allow reconstructing element fluxes and nutrient cycling.

Within all ITS several fields will be selected for sampling of an indicative plant part at selective stages of plant development (growth stage and plant part will be chosen according to standard procedures, specific for rice). Sampling shall be conducted in cooperation with local stakeholders/ members of the consortium, to allow precise timing and high cost effectiveness. Dried plant samples will be shipped to the Lab of MLU/UFZ for chemical analyses of N, P, K, Mg, Ca and Si. Sampling will be repeated in 3 cropping seasons. Crop sites and adjacent areas will be analysed in terms of microbial diversity and key metabolic functions

Task 2.1.2: Biodiversity Relevance for Nutrient Cycles, Production & Water Provision

Work will start with an inventory of selected species groups, with a special focus on native and alien plant species, damselflies and dragonflies. In each the 4 AoIs vascular plant species composition and abundance will be inventoried. Detailed plot-based samples of vascular plants and their quantities will be performed in each ITS separately for fields and their surroundings. Soil samples for seed bank analyses will be collected in each biogeographic region, along gradients of land-use intensities, in coordination with other LEGATO WP 2 partners. Species number proportions of functional types, as well as functional and phylogenetic diversity of the agricultural fields and the surroundings will be related to crop yield while controlling statistically for nutrient input/soil nutrient content/agricultural management (incl. water management). Hence it will be possible to reveal the specific structural relationships between agricultural management, yields and biodiversity. The relative influence of native and alien species will be quantified separately.

The importance of landscape structure, land and water use intensity on the diversity and abundance of decomposers, invertebrate predators and insect herbivores in rice fields and the surroundings will be examined. Intensity of feeding pressure by insect pest species on crops will be assessed.

In cooperation with other groups within LEGATO (which focus on the sites adjacent to crop sites) we will analyse the main chemical properties of topsoil samples, i.e. C_{org}, CEC, pH, N_{min}, P, K available. The results of chemical analyses of the samples will be compiled and the results interpreted.

Task 2.1.3: Climatic Effects on Nutrient Cycles, Production & Water Provision

The provision and evaluation of climate and land (and water) use data will be conducted by communicating the data and modelling constraints of global data sets to local experts and field experimentalists and vice-versa by reporting evaluation results and region-specific constellations to WP1.2 and the GLUES coordination project (PIK). This will bridge region-specific expertise and modelling experiments. The scenarios of global climate and land use change as evaluated in Task 1.2 will be provided to all partners in WP 2.1.3. The documentation of the scenario data sets will include relevant scenario information, i.e., assumptions, parameterisation and experimental settings used in the simulation experiments. In this task the AoIs will be provided with relevant climate data and land use information and they will be supported in the search of historical climate (incl. precipitation) data, where available. The second stream of information will be the assemblage of region-specific information of the AoIs to evaluate global-scale scenarios and identify constraints that these large-scale scenarios have to meet. This will feed into the iterative process to adapt global-scale models to region-specific conditions. These basic data will also be used for Tasks 2.2.3, 2.3.3, 3.0, 3.1.3, 3.2.3, 3.3.3, 3.4.

Work will start with the analysis of the impact of climate change scenarios on nutrient cycle and water balance of agro-ecosystems. Additionally, we will analyse the impact of water and nutrients, e.g., on plant growth, crop yield, plant diseases, nutrient accumulation of cash crops. The results will be compared with the actual situation. To minimise negative impacts on agricultural production, on nutrient cycle, especially to avoid nutrient losses and to assure an efficient water use by crop plants, appropriate adaptation measures have to be developed together with the farmers (e.g., optimising soil tillage, adaptation of crop plant fertilisation, cultivation of new crop plants, change of crop rotation, optimising water management). On this base, we will identify the existing degree of adaptation options, the practice of compensation for extreme events for farming among the stakeholders and their assessment of potential effectiveness. Based on a stakeholder focused scenario approach, adaptation actions will be selected and evaluated in an integrated assessment, with a special emphasis on soil, water and nutrient conservation.

Task 2.1.4: Effects of the Social System on Nutrient Cycles, Production & Water Provision

Besides the objective conditions (environment and climate, landscape structures, need for synchronisation of works), farmers' choices for the kind and intensity of land use and water management are influenced by intrinsic motivations (preferences, traditions, group acceptance) and external constraints and drivers (ownership structures, subsistence levels – i.e. how much of the necessary family income can be generated by rice farming, and the resulting need for additional income and/or migration, access to water and other inputs, suitability of inputs in the specific situation – e.g. no heavy equipment in rice terraces, age structure of the farming communities, but also demand and export prices). Social structures and stratification are related to access to inputs, with subsequent influence on nutrient cycling.

These influences of the socio-cultural system and the economic framework conditions will be analysed by means of mainly qualitative social research (only occasionally semi-quantitative results are expected to emerge). Through semi-structured interviews on household level, as well as participatory rural appraisal methods (such as resource mapping) and farmer participatory research insights into traditional land management of the local people will be gained on both levels, temporal and spatial. Experiments based on the Theory of Planned Behaviour TPB will allow to link the level of knowledge to actual farming practices, production levels and water use patterns, providing the opportunity for nutrient cycle analysis. For more details on the methods see WP 3.3; as the socio-cultural data collection must be condensed into a limited number of interviews and focal groups, data will be collected simultaneously for WP 2 and 3.

In particular it will be possible to identify the ESS recognised as such by local residents (the ESS beneficiaries), in particular crop production (closely linked to water provision), and to find out if the perceived sources of these services, the service providing Units SPU, include nutrient and water cycles (in the respective cultural coding). These results can then be linked to Nutrient Cycles, Production and Water Provision to see in how far the stakeholders are aware of the need to sustain nutrient and water cycles to stabilise the crop production, and which rules and mechanisms exist for this behalf (including specific cultural coding). If deficits are detected, they are fed into the adaptation options developed in task 2.1.3.

Milestones (Results & Products)

M 2.1.0 (2015 Feb): Document describing the relationship between Nutrient Cycles, Production & Water Provision with the suite of drivers used in LEGATO.

Task 2.1.1: Land Use Impacts on Nutrient Cycles, Production & Water Provision

M 2.1.1.1: (2012 Feb): Final document compiling all maps and site descriptions regarding land-use.

M 2.1.1.2 (2012 Feb): Soil profile description of dominant soil type at selected sites.

M 2.1.1.3 (2012 Aug): Report of compiled information on nutrient availability, potential storage and turn-over.

Task 2.1.2: Biodiversity Relevance for Nutrient Cycles, Production & Water Provision

M 2.1.2.1. (2012 Aug): Data on vascular plant species diversity per AoI will be available.

M 2.1.2.2 (2013 Feb): Manuscript on the composition, distribution and abundance of vascular plant species for each ITS.

M 2.1.2.3 (2013 Aug): Manuscript on diversity and abundance of functional groups of invertebrates (decomposers, predators, parasitoids, herbivores) and levels of herbivory by insect pest species on crop plants in the ITS.

M 2.1.2.4 (2015 Feb): Structural equation diagram of the relationships between elements of biodiversity, nutrients availability and agricultural production/land and water management.

Task 2.1.3: Climatic Effects on Nutrient Cycles, Production & Water Provision

M 2.1.3.1 (2013 Aug): Model to relate the region, the change and the interaction between the environment factors and impacted systems will be available.

Task 2.1.4: Effects of the Social System on Nutrient Cycles, Production & Water Provision

M 2.1.4.1 (2012 Aug) Documentation of the perception of nutrient and water cycling and its link to production in the different farming communities, deciphering the cultural codes used to describe the links in the respective cultures (a precondition for the dissemination phase)

M 2.1.4.2 (2015 Feb): Report on the impact of social and economic structures, systems and hierarchies on production management and the way nutrient and water cycles are addressed is available.

Work package number	2.2	Strand 2: Biocontrol & Pollination				Start: 2011 Sep	
Partner	UGOE	IRRI	TUM	UFZ	MLU	MARDI	IEBR
Personmonths (PM)	42	35	27	22	16	14	11
Partner	UFZ (LUPO)	UGR	IRRI (MARD)	OLANIS	PhilRice	PIK	TOTAL
Personmonths (PM)	11	4	6	4	4	2	196

Objectives

- To assess the relationship between Biocontrol and Pollination with the suite of drivers used in LEGATO.

Task 2.2.1: Land Use Impacts on Biocontrol & Pollination

- In general, to assess the relationship between land use parameters such as agricultural (and water) management, land use structure and land use intensity of the surrounding landscape with the abundance of weeds and pest species as well as bio-control organisms in rice fields.
- To test the influence of land and water use intensity and farming practice on the resilience of biocontrol systems.
- To assess the impact of agricultural practices on pollination networks and biocontrol systems.
- To assess population size, genetic diversity and pathogen load of selected pollinator species in response to land use.
- To assess species richness and abundance of cavity nesting bees and wasps and their natural enemies in relation to land use.
- To analyse of the relationship between land and water use characteristics and the impact of insect pests on crop plants.
- To quantify the relationship of land and water use intensity and farming practice on plant weed communities.

Task 2.2.2: Biodiversity Relevance for Biocontrol & Pollination

- To test the impact of apiculture on pollinator biodiversity.
- To evaluate the relationship between plant functional types and pollinator communities and functional structure.
- To assess the abundance of weeds and pest insects as well as biocontrol organisms in rice fields and the surrounding landscapes.
- To test the influence of regional species diversity on the resilience of biocontrol systems.

Task 2.2.3: Climatic Effects on Biocontrol & Pollination

- To assess the impact of weather, climate and climate change on pollination networks including higher tropic levels such as parasites and pathogens.
- To assess the impact of weather, climate and climate change on biocontrol systems.

- To provide preliminary climate change adaptation options to reduce vulnerability of rice based agricultural systems in Asia.
- To relate the abundance of weed species and their contribution to pollinator networks to regional climate.

Task 2.2.4: Effects of the Social System on Biocontrol & Pollination

- To assess the impact of modern beekeeping practice with introduced European bees on traditional beekeeping practice in SE-Asia.
- To evaluate the influence of traditional land and water management practices on pollination networks as well as biocontrol systems.

Description of work

Task 2.2.1: Land Use Impacts on Biocontrol & Pollination

The analyses will be done with ecological DNA tools to quantify the impact of different types of land use on pollinator populations .We will sample bee pollinators in agricultural and adjacent, not agriculturally used, sites using a paired site approach to eliminate the effects of climate and geography on pollinator biodiversity. Population ecological and population genetic analyses will allow us to identify if land use has a negative impact on pollinator diversity. The EU ALARM project revealed the limitations of traditional ecological and taxonomic approaches to quantify the link between bees and ecosystem function. We will compare bee pollinator biodiversity between agricultural and adjacent sites using microsatellite DNA population analyses to determine the genetically effective population sizes (colony density for social species) of widespread selected species (Colletidae, *Apis*, *Bombus*, Megachilidae)

The abundance of weedy and other pest species in field sites will be related to the land use structure and land use intensity of the surrounding landscape. For this focal (groups of) organisms will be chosen such as alien plant species, pest insects etc. and its abundance and frequency assessed. These measures will be related to landscape structure measures such as land use identity (land use classes), size of specific land-uses, and selected landscape metrics (e.g., patch numbers, length of margins, size of woodlands, hedgerows or other greenveining structures). This will be related statistically by advanced methods considering spatial as well as phylogenetic relationships. In a similar vein, the abundance and frequency of biocontrol organisms and pollinator species, pollinator networks and their functional properties in field sites will be related to landscape properties. As higher trophic level species such as parasites, parasitoids, and pathogens play key roles in the structure, function, and stability of ecological communities, their diversity and abundance will also be related to landscape properties.

Task 2.2.2: Biodiversity Relevance for Biocontrol & Pollination

We will use microsatellite DNA analyses of males (particularly in early season) to determine frequencies of diploid drones in non-*Apis* bees to reveal inbreeding Microsatellite DNA analyses of trapped *Apis mellifera* and/or *A cerana* drones (n=200 per site/year) will be used to determine the number of feral and managed honeybee colonies in the sampling areas. The sampled bee pollinators will be screened for pathogen spill-overs focusing on major, well-characterised diseases. We will test for pathogen transmission and its impact on wild pollinator communities in the field using high resolution genetic detection methods to identify those members of the bee community most at risk from pathogen spill-over. Wild bees (n=400 per site/year) will be assayed for the well characterised pathogens of know from api- and bombiculture (PCR-RFLPs).

Specific traits of plant species related to pollination will be assessed, such as type of flower, type of blossom, colour, flowering time, number of flowers, form of flowers. Using multivariate techniques, pollination functional types will be derived. Similarly, the pollinators will be grouped according to their host plant specificity, their body size, wing lengths, tongue length will be classified into functional groups. These will be cross-correlated, i.e., assessing the plant diversity (native and alien) related to specific pollinator functional groups and the pollinator diversity related to specific plant functional types. Furthermore, the relationship between the different functional groups of plants and pollinators will be assessed. Phylogenetic relationships as well as phylogenetic diversity will be recognized if appropriate.

Biocontrol systems will be classified according to their control processes/mechanisms and their specificity for pests (jointly with task 2.2.4). This will be related to measure of taxonomic, functional and phylogenetic diversity of elements of biodiversity such as plant species, damselflies and dragonflies. Advanced statistical techniques will be used to account for temporal dynamics as well as evolutionary constraints.

Task 2.2.3: Climatic Effects on Biocontrol & Pollination

The provision and evaluation of climate as well as land and water use data will be conducted by communicating the data and modelling constraints of global data sets to local experts and field experimentalists and vice-versa by reporting evaluation results and region-specific constellations to WP1.2 and the GLUES coordination project (PIK). This will be done in close collaboration with all partners in this task (see a more detailed description in WP 2.1.3).

The impact of climate change on pollination networks, including higher tropic level species, such as parasites, parasitoids and pathogens, will be assessed at several spatial scales. Using large scale distribution models, the general vulnerability of pollinator species will be assessed. Small scale analyses in heterogeneous field sites or landscapes with large environmental gradients (e.g., high mountain regions) will complement such studies at more local scale and account for small-scale environmental heterogeneity. Furthermore, the interaction between pollinators and pollinated species in terms of temporal (seasonal) and spatial mismatch will be assessed as far as possible. The classification of biocontrol systems elaborated jointly with task 2.2.4 will be used to model the impacts of climate change on such systems in a similar vein as briefly outlined for pollinators. The impact of climate change on selected weedy/alien species in the field sites will be analysed at small and large scale. The interactions of alien species with native species will be evaluated.

Task 2.2.4: Effects of the Social System on Biocontrol & Pollination

Both native *A. cerana* honeybees as well as introduced European *A. mellifera* are used for apiculture. We will screen how the use of large scale apiculture with *A mellifera* has changed traditional beekeeping practices. We will assess the changes by screening the density of non *A mellifera* apicultural operations in relation to apiculture with native honeybees (including all giant and dwarf honeybee species).

We aim at modelling the relationship between pollinator functional groups or biocontrol systems, respectively, and traditional land and water use types or management practices. The former will results from the previous tasks while the latter will build on the socioeconomic results. In this context methods will draw from qualitative social research. Through semi-structured interviews on household level, as well as participatory rural appraisal methods (such as resource mapping) insights into traditional land and water management of the local people will be gained on both levels, temporal and spatial. These results can then be linked to those of pollination and biocontrol. Elements of the social system which are very beneficial as well as those that are detrimental for pollination and biocontrol services can hence be identified and appropriate management recommendations be deducted.

Milestones (Results & Products)

M 2.2.0 (2015 Feb): Document describing the relationship between Biocontrol and Pollination with the suite of drivers used in LEGATO.

Task 2.2.1: Land Use Impacts on Biocontrol & Pollination

M 2.2.1.1 (2012 Feb): Review: Agricultural intensification, landscape structure, and water management and its effects on biocontrol agents in rice based agro-ecosystems.

M 2.2.1.2 (2012 Feb): Review: Agricultural intensification, landscape structure and the indicator role of pollinators for biocontrol agents in rice based agro-ecosystems.

Task 2.2.2: Biodiversity Relevance for Biocontrol & Pollination

M 2.2.2.1 (2014 Aug): Report on the relationship between plant functional types and pollinator communities and functional structure will be available.

M 2.2.2.2 (2014 Nov): Report on the relationship between alien and native plant species composition and diversity of pollinators and biocontrol organisms.

Task 2.2.3: Climatic Effects on Biocontrol & Pollination

M 2.2.3.1 (2014 Feb): Model relating climatic covariates (incl. water provision) to pollinators and biocontrol systems will be available.

Task 2.2.4: Effects of the Social System on Biocontrol & Pollination

M 2.2.4.1 (2012 Aug): Draft document results for traditional farming practices of local inhabitants.

M 2.2.4.2 (2014 Feb): Draft document impact of modern bee keeping on traditional bee keeping practices.

M 2.2.4.3 (2014 Nov): Evaluation of traditional land and water management on pollination networks and biocontrol systems.

Work package number	2.3	Strand 3: Cultural Identity & Aesthetics				Start: 2011 Sep
Partner	CEPSTA	IRRI (VSU)	UGR	IEBR	UFZ (LUPO)	UFZ	
Personmonths (PM)	33	27	21	9	6	6	
Partner	S4U	IRRI (MARD)	UAB / ICTA	OLANIS	PIK		TOTAL
Personmonths (PM)	5	4	3	3	2		118

Objectives

- To assess the relationship between Cultural Identity and Aesthetics with the suite of drivers used in LEGATO.

Task 2.3.1: Land Use Impacts on Cultural Identity & Aesthetics

- To assess the perceptions of stakeholders and land users on how past and present land use and water management has changed cultural identities and as far as this category applies, the aesthetics of landscapes.
- To develop information packages on land and water use impacts for policy makers, extension, farmers, NGOs, integrated with the information provision elaborated in WP 4.

Task 2.3.2: Biodiversity Relevance for Cultural Identity & Aesthetics

- To evaluate the relationship between native and alien elements of biodiversity and the perception of landscapes.
- To assess the influence of local identity and the behavioural patterns influenced by it on biodiversity.

Task 2.3.3: Climatic Effects on Cultural Identity & Aesthetics

- To assess the impact of climate on architecture, landscape and water management and farmers' self perception
- To assess the aesthetic value of the landscapes for attractiveness to tourists.

Task 2.3.4: Relevance of the Social and Economic System for Cultural Identity & Aesthetics

- To assess the influence of education level on local identity and attachment to specific landscapes.
- To investigate the role economic conditions play for local identity and the attachment to the landscape and its farming methods (landscape as a source of subsistence).
- To provide options (training activities) for education (integration of school classes).

Description of work

Task 2.3.1: Land Use Impacts on Cultural Identity & Aesthetics

Understanding stakeholder perceptions of the impacts of land use will facilitate the development and use of monitoring tools to assess current land use practices, and communicating its importance to key stakeholders. Both formal and informal approaches will be used to assess perceptions of impacts using focus group discussions and ethnoscience techniques. Ethnoscience is the study of perceptions, knowledge and classification of the world as reflected in the use of language. The end in view is to engage stakeholders and land users to regulate land use and water management practices that impinge on cultural values and aesthetics of landscapes.

Task 2.3.2: Biodiversity Relevance for Cultural Identity & Aesthetics
The local perception of the landscape will be assessed in relation to species number and diversity. The aim is to analyse in how far the perception of the local population is influenced by measurable aspects of biodiversity and how far people are willing to contribute to biodiversity. Similarly, the importance of local identity as a prerequisite for taking responsibility for the preservation of biodiversity but also the acknowledgement of the ESF/ESS will be assessed. The outcome of this task is closely linked to task 2.3.4 and will serve as triangulation basis for comparing and complementing the results.

Task 2.3.3: Climatic Effects on Cultural Identity & Aesthetics
Landscape and architecture are crucial elements of local identity and –as man-made traits – of aesthetics. These are among the main values for tourist attractiveness and impacted by climate. We will address this field by documenting dwellings and houses in the research areas with pictures, develop a criteria catalogue regarding climatic effects on different house types and will try to show examples of well-embedded and environmentally-friendly construction in the areas. A workshop we will organised where we will discuss the findings together with architects. The public will be involved in the documentation by a picture contest on the project website. Each region will be examined for existing touristic projects and the potential impact by climatic changes. Climatic baseline information will be provided analogous to task 2.1.3.

Task 2.3.4: Relevance of the Social System for Cultural Identity & Aesthetics
We will combine aspects of the aesthetics of landscapes and its elements (structure, “beautiful” and “attractive” sceneries and species living in the landscape – as far as such categories are applicable to natural environments in the respective cultures) with the analysis of subsistence levels and the education of the broader public. Both elements are closely linked to local identity. It is reported for some South-East Asian countries that the identification with the rural landscape and inherited traditions seems to increase with higher levels of education, and with the capability to feed a family from the land available.
For data collection a qualitative social research approach drawing from an existing pool of proved methods for participatory inquiry (e.g. Participatory Rural Appraisal methods, Planned Behaviour Analyses) will be applied. Using different techniques (interviews, interactive workshops, visualisation of landscapes) we will ensure to engage people from all levels of education to express their identity and attachment to the landscape, and – as far as possible – the determining factors. Furthermore, secondary data collection will be based on relevant freely available datasets (e.g. socio-economic characteristics of the specific areas under study: gender, age, education level). In order to reach the next generation of decision makers, we will explore options (training activities) to integrate schools into the activities.

Milestones (Results & Products)

M 2.3.0 (2015 Feb): Document describing the relationship between Cultural Identity and Aesthetics with the suite of drivers used in LEGATO.

Task 2.3.1: Land Use Impacts on Cultural Identity & Aesthetics

M 2.3.1.1 (2013 Aug): Draft document on perceptions and non-monetary valuation of local stakeholders in aesthetics and local identity.

M 2.3.1.2 (2015 Feb): Voting system for stakeholder involvement in monitoring.

Task 2.3.2: Biodiversity Relevance for Cultural Identity & Aesthetics

M 2.3.2.1 (2013 Aug): Draft document local perception of landscapes.

M 2.3.2.2 (2015 Feb): Review: the role of local identity for the conservation of biodiversity

Task 2.3.3: Climatic Effects on Cultural Identity & Aesthetics

M 2.3.3.1 (2013 Feb): Report on climatic effects on architecture and tourism.

Task 2.3.4: Relevance of the Social System for Cultural Identity & Aesthetics

M 2.3.4.1 (2013 Aug): Draft document influence of income, education and production self-sufficiency levels on local identity.

M 2.3.4.2 (2015 Feb): Review: options (training activities) for education.

Work package number	**2.4**	**Summary across Tasks**				Start: 2012 Sep	
Partner	CEPSTA	UFZ	IEBR	TUM	UGR	UGOE	
Personmonths (PM)	8	7	6	6	5	4	
Partner	IRRI (VSU)	PIK	MARDI	OLANIS	IRRI (MARD)		TOTAL
Personmonths (PM)	4	3	3	3	1		48

Objectives

- To assess the relationship between land and water use and ESF/ESS.
- To assess the relationship between biodiversity and ESF/ESS.
- To assess the relationship between climate and ESF/ESS.
- To assess the relationship between social systems and ESF/ESS.
- To derive a conceptual framework on the relationships between drivers and ESF/ESS.

Description of work

The results and in particular the models developed in the previous tasks regarding the relations of influence factors like land and water use, biodiversity, climate and social systems to ESF/ESS will be harmonised, streamlined and combined. For the provisioning and regulating services, this can be done directly by describing the role of the above factors for these ESS, as done in the previous tasks. For socio-cultural services, the results will be used to identify the service providing units, documenting their relation to the above factors. This will allow the development of a common modelling framework to consider the above mentioned aspects for the three strands recognized in LEGATO.

Milestones (Results & Products)

[As an input from WP 3, the identification of SPUs for the socio-cultural ESS will be used in elaborating the milestones.]

- **M 2.4.1 (2014 Aug):** Draft document describing the relationship between ecosystem services and land use (incl. water use).
- **M 2.4.2 (2014 Aug):** Draft document describing the relationship between ecosystem services and biodiversity.
- **M 2.4.3 (2014 Aug):** Draft document describing the relationship between ecosystem services and climate.
- **M 2.4.4 (2014 Aug):** Draft document describing the relationship between ecosystem services and social systems.
- **M 2.4.5 (2015 Aug):** Synthesis paper providing a conceptual framework for the relationship between land and water use, biodiversity, climate, social systems and ecosystem services.

12.3 WP 3: Driving Factors of ESF/ESS (experiments)

Overall responsibility of WP 3: Roland Brandl (UMAR) in close cooperation with Dao Thanh Truong (CEPSTA; Vietnam) and Dr. Escalada (VSU, Philippines).

General aims of the WP: Within selected experimental sites and facilities which relate to rice based systems (see Table 6.2), natural and social science experiments will be conducted to assess the impacts of selected pressures (land use, water management, climate, economic situation and social system) and biodiversity on the LEGATO ESF/ESS strands. Analyses should reveal selected relevant causal relationships which clearly go beyond the purely correlative approaches in WP 2. However, due to the higher level of effort, only a limited set of interactions can be tested. Baseline data have to be compiled and/or collected in close cooperation with research institutions (including the ones who are LEGATO partners: UFZ, UMAR, IRRI, PhilRice etc.) which provide the facilities.

Work package number	**3.0**	**Sites & Protocols**				Start: 2011 March	
Partner	UFZ	MLU	PhilRice	IEBR	UFZ (LUPO)	PIK	
Personmonths (PM)	7	6	3	3	2	2	
Partner	UMAR	CABI	UGOE	UGR			TOTAL
Personmonths (PM)	2	1	1	1			26

Objectives

- To establish a network of experiments regarding driving factors of ESF/ESS generation in the different study regions. The use of common set-ups, designs and methods is essential for a synthesis of the effects of land and water use, biodiversity, climate and social systems on productivity as a provisioning ESS.
- To agree on field experiments and the detailed protocols and their implementation on the different experimental sites
- To agree on a procedural method for the selection of candidate species and model systems for experimental implementation.
- Coordination of common experiments both in the field and in the laboratory which can be used by different partners.

Description of work

This WP aims to establish a network of working groups which experimentally assess the relationship between land and water use, biodiversity, ecosystem functions and provisioning and regulating ecosystem services. We will coordinate the sampling schemes, the standardisation of experimental protocols and the selection of model systems. A database of characteristics of experimental sites will be established and made available to the partners. To fully benefit from the expertises of partners and the available resources, the set-up of common experiments for several partners both in the field as well as in greenhouses and labs will be coordinated.
The combination of experimental data with the results of WP 2 will result in a synthesis of the effects of land use intensity, water management, landscape structure, climate, local economy and social systems on biodiversity and biotically driven ecosystem functions and services. Data from the experiments will be prepared and combined for the use in risk assessment tools, monetary and non-monetary evaluations of these ecosystem services and suggestions for sustainable land and water use and management strategies.

Milestones (Results & Products)

- **M 3.0.1 (2011 May)**: 1st project workshop to agree on field experiments and the detailed protocols and their implementation on the different experimental sites.
- **M 3.0.2 (2011 Nov):** Data provision to LEGATO partners (land & water use, inputs etc.)
- **M 3.0.3 (2012 Feb)**: Presentation and final discussion on experimental designs and core elements of investigation in field trials in farmers' fields; preparatory work for implementation of experiments
- **M 3.0.4. (2012 May):** Final document on experimental designs and core elements of investigation in field and laboratory/greenhouse trials provided to all partners.

Work package number	**3.1**	**Strand 1: Nutrients, Production & Water Provision**				Start: 2011 Sep	
Partner	MLU	UFZ	UMAR	IRRI	IEBR	PhilRice	
Personmonths (PM)	22	16	15	11	10	6	
Partner	UGOE	CABI	UFZ (LUPO)	PIK	UGR		TOTAL
Personmonths (PM)	5	5	2	2	1		95

Objectives

- To disentangle the functional relationships between different drivers of ESF and provisioning/regulating ESS and water provision, nutrient cycling and productivity in agricultural systems in the LEGATO study regions.
- To develop a conceptual synthesis of feedback mechanisms between land and water use, biodiversity, climate and social systems, providing input to the DPSIR analysis in WP 4.

Task 3.1.1: Land Use Impacts on Nutrient Cycles, Production & Water Provision

- To assess the impact of modified (climate adapted) land and water use systems on production and nutrient cycling
- Quantification of biotically driven decomposition dynamics and nutrient cycling
- Detailed investigation of Si and N transformation for selected sites. Compare the intensity of Si and N transformation for different systems based on the distribution of the elements across different soil fractions and their contribution to transformation processes.
- Investigate Si mobilisation by rhizosphere processes for a flooded rice system for different soil types and water regimes under controlled conditions.

Task 3.1.2: Biodiversity Relevance for Nutrient Cycles, Production & Water Provision

- To provide information on ecosystem effects of decomposers with regards to nutrient cycling, plant and crop nutrition, water provision and productivity
- To provide knowledge about the consequences of reductions of ecosystem functions driven by land and water use induced biodiversity changes to local farmers and decision makers.

Task 3.1.3: Climatic Effects on Nutrient Cycles, Production & Water Provision

- To assess the impact of weather, climate and climate change on water provision and nutrient cycling

Task 3.1.4: Effects of the Social System on Nutrient Cycles, Production & Water Provision

- To provide insights into local knowledge concerning traditional and modern water management, fertilization and its application
- To explore local people's knowledge concerning key organisms and ecosystem effects regarding nutrient cycling, productivity and water provision
- To assess local knowledge on land and water management techniques to optimize nutrient cycling and productivity

Description of work

Task 3.1.1: Land Use Impacts on Nutrient Cycles, Production & Water Provision

Field experiments will be conducted on the impact of modified (climate adapted) and ecological engineering oriented land use systems on production, water provision and nutrient cycling. Modified systems aim at reduction of erosion, less water use and efficient use of nutrients (e.g., through direct seeding, depot fertilisation), while securing crop production. The field experiments will be elaborated and conducted with all LEGATO partners involved in WP 3 and additional field investigations (incl. modelling of water budget, soil erosion and N- as well as C-cycles on patch and catchment level) will be elaborated. This will be performed on farmer's fields to demonstrate climate adapted land use strategies.

The dynamics of the decay of organic matter along gradients of land and water use intensity will be examined in decomposition experiments and the relative contribution of different biotic drivers will be experimentally assessed by suitable exclusion techniques.

For the detailed investigation of Si and N transformation and based on results from task 2, topsoil samples will be selected for detailed analyses of phytoliths. Phytoliths are plant derived Si-minerals, expected to contribute substantially to available Si fraction, but may also entrap organic matter which is thus not available for mineralisation.

The size of the phytolith fraction will be determined and Si availability will be determined using specific extractants and a procedure for obtaining soil solution under standardized conditions. In addition, parameters important for Si sorption in soil (Fe(hydro)oxides) will be investigated in detail. Other Si sources apart from phytoliths, like clay minerals and quartz will be quantified. Soil samples will be incubated under changing redox (and thus water supply) conditions mimicking different field situations for paddy rice with continuous flooding to intermediate flooding. Redox cycling is supposed to affect Si-mineral weathering as well as N mineralisation.
To evaluate the intensity and importance of Si transformation in rice cropping system a compartment system experiment will be conducted in a plant growth chamber under controlled conditions. For this study topsoil samples from a paddy field will be selected. Additional treatments enriched with phytolith obtained from rice straw ash will be established. During the experiment soil solution will be sampled weekly with increasing distance from the root surface. At harvest Si concentration in different plant parts and in soil slices, obtained with increasing distance from the rhizosphere, will be determined.

Task 3.1.2: Biodiversity Relevance for Nutrient Cycles, Production & Water Provision

The dynamics of litter decomposition and the contribution of soil fauna to decomposition will be assessed using litter bag experiments on the same sites where soil diversity will be assessed by WP2. We will use a correlative approach to relate field data on soil biodiversity to dynamics of litter decomposition with and without soil invertebrates. Litter transplant experiments, decomposition studies in common gardens and the use of standardized organic material in decomposition studies on the different field sites will enable us to disentangle (1) the effects of land and water use on decomposition dynamics induced by biodiversity change, (2) the effects of land and water use on the quality of produced organic material, and (3) the effects of adaptation of the decomposer community to local conditions and/or land and water use traits.

Task 3.1.3: Climatic Effects on Nutrient Cycles, Production & Water Provision

We will combine data sets on experimentally assessed ecosystem processes related to nutrient cycles, production and water provision (decomposition, mineralization, plant growth and nutrition) to climate data across and within main study regions, AoIs and ITS. Using statistical methods, climatic variables which contribute strongest to the observed effects will be determined. The impact of climate on nutrient cycles, production and water provision in specific rice agro-ecosystems will result in a synthesis and a modelling approach of the consequences of region specific climate change scenarios on current and suggested future crop systems. For this, scenario data sets as evaluated in task 1.2 will be used. We will evaluate how these climate change scenarios can be integrated in concepts on sustainable land use.

Task 3.1.4: Effects of the Social System on Nutrient Cycles, Production & Water Provision

In close collaboration with WP 3.3, socio-cultural field experiments will be conducted to get a deeper insight into local knowledge concerning nutrient cycling and productivity, fertilization application, and land and water management techniques to optimise productivity. Work will start with questionnaire-based data collection on these topics in combination with socio-economic as well as social structure information. Interviews will be performed on household level with farmers living in the investigation area. Men and women, farmers at different ages, with different education levels will be interviewed to test the effect of such factors in order to formulate hypotheses.

Milestones (Results & Products)

Task 3.1.1: Land Use Impacts on Nutrient Cycles, Production & Water Provision

- **M 3.1.1.1 (2012 Feb):** Experimental set-up of decomposition experiment along land (and water) use gradients
- **M 3.1.1.2 (2012 Sep):** Selection of soil samples based on results of task 2 for investigations on Si-transformation
- **M 3.1.1.3 (2013 Apr):** Selection of soil samples for investigation of phytolith (Si)-weathering
- **M 3.1.1.4 (2013 Oct):** Set-up of experiment for investigation of phytolith (Si)-weathering
- **M 3.1.1.5 (2014 Jan):** Establishment of methods and experimental conditions for investigations on Si-transformation finished
- **M 3.1.1.6 (2014 Aug)** Reports on process understanding for Si-transformation and availability for different soil types and impact of vegetation and water regime on Phytolith (Si)-weathering

Task 3.1.2: Biodiversity Relevance for Nutrient Cycles, Production & Water Provision

- **M 3.1.2.1 (2012 Feb):** Draft document on selection of sites for decomposition experiments in the ITS.
- **M 3.1.2.2 (2012 Nov):** Document on selection of model organisms for lab experiments with site and land (and water) use type specific decomposers to assess their specific contribution to ecologically and economically relevant ecosystem functions.
- **M 3.1.2.3 (2013 Aug):** Report and publication of the synthesis of soil biodiversity data and decomposition dynamics in the ITS depending on land use (incl. water management) traits. Set-up of functional experiments under controlled conditions on the effects of specific decomposer organisms.

Task 3.1.3: Climatic Effects on Nutrient Cycles, Production & Water Provision

- **M 3.1.3.1 (2014 Feb):** Draft document on climate driven differences in the experimentally assessed dynamics of ESF/ESS related to nutrient cycling, water supply and production across and within study regions
- **M 3.1.3.2 (2015 Feb):** Draft document on the synthesis of results from M 3.1.3.1, region specific climate change scenarios and land use changes with suggestions for integration in concepts on sustainable land use.

Task 3.1.4: Effects of the Social System on Nutrient Cycles, Production & Water Provision

- **M 3.1.4.1 (2012 Feb):** Draft document on household selection and interview guidance
- **M 3.1.4.2 (2014 Feb):** First results on local knowledge concerning nutrient cycling, water management, productivity and related key species (list of indicators)
- **M 3.1.4.3 (2015 Feb):** Draft document on local land and water management techniques in order to optimize productivity

Work package number	**3.2**	**Strand 2: Biocontrol & Pollination**				Start: 2011 Sep	
Partner	UMAR	IRRI	UFZ	PhilRice	UGOE		
Personmonths (PM)	17	10	9	6	5		
Partner	MARDI	UFZ (LUPO)	PIK	~~UGR~~			TOTAL
Personmonths (PM)	5	2	2	~~1~~			57

Objectives

- To assess the influence of land use intensity, land use strategies and water management on the ecosystem services biocontrol and pollination

Task 3.2.1: Land Use Impacts on Biocontrol & Pollination

- To examine the relationship between crop Si and N nutrition and yield loss by insect pest species, by investigating the relationship between plant Si and N status and the degree of damage by plant sucking or eating insects and fungal infection.
- To assess the impact of land use and water level change on intensity of insect herbivory by pest species and consequences for yield loss in rice.

Task 3.2.2: Biodiversity Relevance for Biocontrol & Pollination

- To test experimentally the role of field size for the potential of biocontrol and insect diversity within fields.
- To investigate the functional link between land and water use induced changes of soil biodiversity on interactions between crop plants and insect herbivores
- To investigate the functional role of the decomposer fauna for the maintenance of natural biological control via promotion of predatory biocontrol agents.

Task 3.2.3: Climatic Effects on Biocontrol & Pollination

- To use information on the variability of the impact of pest species and pollinators on plants along climatic gradients within study regions for scenarios of climate change shifts in biodiversity and distribution of key species for crops and natural weed communities.

Task 3.2.4: Relevance of the Social System for Biocontrol & Pollination

- To assess the awareness of farmers regarding the potential valuable contributions of biocontrol to rice yields.
- To document existing practices for safeguarding biocontrol ESS in traditional and modernised land and water use patterns.

Description of work

Task 3.2.1: Land Use Impacts on Biocontrol & Pollination

If screening results from task 4 suggest that cultivars themselves show a large variation in tissue N and Si concentrations which are not directly related to soil N and Si availability additional pot experiments under controlled conditions will be conducted with different cultivars which will then be exposed to a defined economically important pest for rice (i.e. stem borers) and a standard bioassay test species (e.g. cotton leafworm, *Spodoptera littoralis*) to investigate the interaction.

Task 3.2.2: Biodiversity Relevance for Biocontrol & Pollination

A biocontrol experiment will be conducted to assess the importance of various groups of natural enemies for biocontrol. We will also test experimentally the role of field size for the potential of biocontrol and insect diversity within fields.

The consequences of biodiversity loss in the soil due to land and water use changes will be investigated in microcosm experiments with decomposer species selected in task 3.1.2 which respond sensitively to land use changes and importantly trigger important decomposition processes. We will investigate if these belowground interactions affect plant-insect herbivore relationships and therefore also contribute to land use change induced patterns of yield loss due to herbivory. A set of field experiments will be established to assess the functional link between decomposers, herbivores, pollinators and natural biocontrol agents (predatory insects). For this, we will manipulate the decomposer community (via litter supply) and activity of biocontrol agents (exclusion by means of caging) on selected sites in differentially structured landscapes. The resulting net effect of decomposer driven changes in the top-down effects of agents on crop yield will be assessed by insecticide exclusion on experimental plots.

Task 3.2.3: Climatic Effects on Biocontrol & Pollination

Work will start with an analysis of experimentally assessed results on pollination, insect herbivore fauna in (semi-)natural plant communities and feeding pressure of pest species on the rice plants along climate gradients. Using statistical methods, climatic variables which contribute strongest to the observed effects will be determined. Data on predicted shifts in species distribution, land use and water provision changes will be combined to evaluate climatic effects on the region specific impact of pests and potential biocontrol agents. For this, scenario data sets as evaluated in task 1.2 will be used.

Task 3.2.4: Relevance of the Social System for Biocontrol & Pollination
Local farming practices are influenced by a diversity of natural, social, cultural and economic factors. Consequently, the awareness of the actual and potential role of bioregulation cannot be derived only from analysing the current practice, which will be documented for traditional and modernised agricultural systems.

Beyond that, the investigation requires an analysis of motivations as part of the socio-cultural data gathering (see WP 3.3). If in the semi-structured interviews farmers express an awareness of a potentially larger role of bioregulation, inhibiting factors will have to be identified and analysed as part of the recommendations for the implementation phase.

Milestones (Results & Products)

Task 3.2.1: Land Use Impacts on Biocontrol & Pollination.

- **M 3.2.1.1 (2014 Jan):** Draft document on data on the relationship between nutritional status of crop plants and pest damage in relation to land use traits
- **M 3.2.1.2 (2014 Nov):** Synthesis paper on recommendations relevant for practice and sustainable land use regarding economic and ecological benefits and risks of fertilization methods.

Task 3.2.2: Biodiversity Relevance for Biocontrol & Pollination.

- **M 3.2.2.1 (2013 Nov):** Set-up of microcosm experiments on functional links between soil biodiversity and plant-herbivore interactions and set-up of field experiments for investigations of functional links between decomposers and natural biological control
- **M 3.2.2.2 (2015 Feb):** Synthesis paper on the impact of land and water use intensity on functional links between soil biodiversity, productivity, biocontrol and plant-herbivore interactions in rice dominated crop systems.

Task 3.2.3: Climatic Effects on Biocontrol & Pollination.

- **M 3.2.3.1 (2014 Feb):** Draft document on climate driven differences in the impact of pest species on rice and pollinator diversity in weed communities across and within study regions
- **M 3.2.3.2 (2015 Feb):** Draft document on the synthesis of results from M 3.2.3.1, region specific climate change scenarios and land use and water supply changes with suggestions for integration in concepts on sustainable land use

Task 3.2.4: Relevance of the Social System for Biocontrol & Pollination

- **M 3.2.4.1 (2012 Aug):** Interview outcomes regarding biocontrol analysed and results documented
- **M 3.2.4.2 (2014 Feb):** Inventory of biocontrol-supporting established land use practices available

Work package number	**3.3**	**Strand 3: Cultural Identity & Aesthetics**				Start: 2011 Sep	
Partner	CEPSTA	UMAR	VSU	PhilRice	UFZ (LUPO)		
Personmonths (PM)	15	15	10	7	2		
Partner	PIK	UFZ	UGR				TOTAL
Personmonths (PM)	2	1	3				55

Objectives

Task 3.3.1: Land Use Impacts on Cultural Identity & Aesthetics

- To formulate hypothesis concerning the relation of local identity and natural and cultural landscapes of different local stakeholders
- To explore by means of a participatory process the social connotations of aesthetics (beauty – virtue – justice are closely linked in Buddhist writings) and identity (individual vs. social, e.g. by questioning part-time emigrants and farmers with different levels of knowledge regarding ecological engineering)
- To evaluate the diffusion of social learning processes regarding modified land use and water management patterns and their results, identify traditional information exchange and learning systems and make the accessible for project results.
- To assess the influence of certain land and water use patterns on the economic and socio-cultural ecosystem services identified as relevant for the local stakeholders, and vice versa the influence of the identities on land use practices.….
- To develop a preliminary model on how land use and water management changes and associated landscape transformations impact local identity and attachment to specific landscapes

Task 3.3.2: Biodiversity Relevance for Cultural Identity & Aesthetics

- To assess the awareness of, familiarity with and sensitivity for local biodiversity as part of the respective identities, and thus,
- To identify the role of natural and agricultural biodiversity (as part of everyday practices) for local identities
- To provide recommendations for biodiversity, water and landscape management that integrate people's preferences

Task 3.3.3: Climatic Effects on Cultural Identity & Aesthetics

- To provide modelling data regarding the impacts of climate change on the analysed regions as a basis for socio-cultural impact assessment.

Task 3.3.4: Relevance of the Social and Economic System for Cultural Identity & Aesthetics

- To asses in participatory processes how local populations view their own practice as agent of changes in land use, depending on the contribution of land use to family income
- To identify if and how the key socio-cultural ecosystem services perceived as such by the local population are considered to be individual or collective goods and explore the social connotations of aesthetics (beauty – virtue – justice as closely linked in Buddhist writings) and identity (individual vs. social, e.g. by questioning part-time emigrants)

- To identify ownership structures, distribution mechanisms, privileges, exclusions and other socio-structural factors which establish the prevailing pattern of access to services, and which allow certain groups to live on rice farming while others have to look for additional sources of income (which certainly influences their identities)
- To understand how social structures and stratifications were linked to (both as a condition of and inhibiting to) certain land and water use structures and biodiversity conservation mechanisms (e.g. religious or social taboos).

Description of work

Overall: Within this WP, socio-cultural experiments on the topic of local identity among local people in natural and cultural landscapes will be conducted, using methods of qualitative social research, in particular questionnaire surveys and participatory censuses (for examples see below).

Participatory censuses include *social mapping* and *social learning* and are aimed at taking a closer look at the individual household, including information on demographic details, ethnic group details economic conditions to behavioural patterns and their valuation by participants.

One major way of doing participatory censuses are the *social map method* and the *social card method*. Finally, the data generated from participatory censuses will be used for formulating hypothesis concerning the relation of local identity to natural and cultural landscapes of different local stakeholders.

Social learning methods to be adopted in the socio-cultural experiments are farmer participatory research and a participatory exercise to motivate change in cognition and decisions. Farmer participatory research (FPR) approach involves motivating farmers to engage in experiments in their own fields so that they can learn and adopt new technologies (Bunch 1989). New information, technologies and concepts may be effectively communicated to farmers through the FPR approach. To shape learning, interpretations of experience must provide information about what happened, why it happened and whether what happened was satisfactory or unsatisfactory.

TPB (Theory of Planned Behaviour) based knowledge impact analysis, which has been tested with satisfactory results by Asian consortium members, starts with the identification of 3 other wise comparable communities, distinct by their level of knowledge of and experience with ecological engineering: (i) a community with ecological engineering introduced. Farmers continue normal pest management; (ii) a community with ecological engineering and farmers trained on the benefits from bees, etc; (iii) a control community with no ecological engineering experience, and no training. Both ecological and sociological elements in these communities will be monitored. For the ecological impacts, the usual sampling methods apply, while for the sociological effects pre implementation and post implementation farmer surveys will be conducted. The surveys will be designed to capture attributes in beliefs, attitudes, perceive barriers, subjective norm attitudes and practices. The null hypothesis is the interventions do not cause change in farmers' behaviour. The Theory of Planned Behaviour will be used to construct the various decision making variables and develop questionnaire instruments to quantify these variables.

Task 3.3.1: Land Use Impacts on Cultural Identity & Aesthetics

Work will start with conducting participatory censuses by social map method and card method as the basis for formulating hypotheses. A second element is farmer participatory research to motivate farmers to engage in modified land use schemes such as ecological engineering.

For all elements in WP 3 one key challenge will be to derive approaches applicable all across Asia, with the necessary adaptation to local cultural conditions not blurring the results.

Task 3.3.2: Biodiversity Relevance for Cultural Identity & Aesthetics

Work will start with gathering audio-visual material in Asia for biodiversity and culture analysis, and by organising the technical means for the presentations. They will be held (after a method pretest) and used for further characterisation of local cultures and their links to ESS.

In the Philippines and Vietnam, we used an approach to change farmers' perceptions about leaf feeding insects and their insecticide decisions (Heong & Escalada, 1997). Farmers were presented with conflict information framed in the form of a heuristic and invited to test if the new information was true, i.e., spraying insecticides in the early crop stages is generally not necessary. This heuristic, based on many years of scientific research (Way & Heong 1994), is in direct conflict with farmer beliefs. To convince them, systematically designed learning processes are required, but past experience of LEGATO participants shows how this can be done:
Farmers in groups of 5 to 10 are invited to a meeting where the exercise is introduced by a trained facilitator. The meeting starts with the normal introduction, discussions about rice growing and general topics. Farmers are then asked about the stem borer problem and what they normally do about it. To facilitate discussion and information gathering from the group, the facilitator posts Part I of the framework on the board (Table 4.1). Farmers are asked to estimate the density of the white head symptom that is considered highly serious. To help farmers estimate the white head density per m^2, a square sheet of paper trimmed to $1x1m^2$ with drawings of rice hills is used. Then an economic estimate regarding costs and losses is undertaken (see task 3.3.3).
To analyse the meaning of biodiversity for local identities (and regarding aesthetic criteria as far as task 3.1 revealed this as a suitable category), we intend to complement the more verbally oriented interview and discourse style of experiments with associative analysis and optical tools. By using photos or short video presentation, plus or including sound bites (all via laptop computer, e.g. sounds/pictures of singing birds, grain fields, harvesting, or urban road noise) the subjective and emotional reactions can be monitored, by having the clients describe them and by experienced observers familiar with the respective culture. Recognition quotes for sounds and sights provide information about the prevailing knowledge, observation and reporting about the emotional these presentations have for local identities (to do so the bites to be presented have to be chosen based on an extensive knowledge of the respective populations' cultures).

Task 3.3.3: Climatic effects on Cultural Identity & Aesthetics

> [This task will remain open, as there seems no adequate approach possible within LEGATO for the time being. However, based on experience gained from other large multidisciplinary projects (from ALARM in particular) one could easily imagine that a reasonably large research community comes across new ideas and concepts. Thus, we leave this task open. This also helps to maintain the logical structure of the overall work plan.]

Task 3.3.4: Relevance of the Social System for Cultural Identity & Aesthetics

Work will start with questionnaire-based data collection on the ESS as perceived by the local population, in combination with socio-demographic and social structure information. Service definitions will be identified from socio-cultural field research, and their differentiation according to social groups must be taken into account. From the same questionnaire, we will derive preliminary inventories of ecosystem services and rankings reflecting the respective relative importance local stakeholders allocate to different services, and the identification of locally perceived service providing units (SPUs). Economically relevant data will either be derived

trough the questionnaire, or through participatory processes. The moderated farmers' meetings as described above include – following a discursive assessment of "white head" infection rates – an economic self-assessment: The next question is the amount farmers spent to prevent white head symptoms in the previous season. This is followed by farmers' estimated loss in yield if no control action is taken. From the price of rice, the estimated yield loss is then converted to costs. The insights generated from these valuations (in LEGATO essentially a part of WP 4.1, but described here due to the process context) impact the perception of the ESS's social cost and monetary value, and thus local identities and socio-cultural ESS.
In a later stage, plausible estimates will be developed how social cohesion, local cultures, identities etc. will be affected by changing land use patterns (due to modernisation, growing population etc.) und the increasingly uncertain framework conditions for agricultural production (Lowlands: flooding from inland due to heavy precipitation in humid regions, flooding from the sea due to rising sea levels and sinking ground levels due to overexploitation of freshwater aquifers, Highlands: problems of maintaining terrace cultures,... overall: uncertainty of water supply and erosion problems). The estimates will be based on the scenarios and the experience from the social learning processes induced, the impacts of changing land use on the interaction of identities and social structures. They will be analysed by desk top work and participatory observation reflected in discussion groups. This is the basis for qualitative input into the scenario refinement, and the evaluation of diffusion success of the social learning experiments.

Milestones (Results & Products)

Task 3.3.1: Land Use Impacts on Cultural Identity & Aesthetics

- **M 3.3.1.1 (2012 Feb):** Draft document on social mapping and identities
- **M 3.3.1.2 (2012 Aug):** Social maps or card mosaics for the test sites
- **M 3.3.1.3 (2014 Feb):** Preliminary model on how land use and water management change impact local identity

Task 3.3.2: Biodiversity Relevance for Cultural Identity & Aesthetics

- **M 3.3.2.1 (2012 May):** Using the collection of audio-visual material and the infrastructure (available at about 2011 Nov) the first social experiments as described above will be conducted.
- **M 3.3.2.2 (2013 Aug):** Draft document on the relevance of biodiversity for local identities in the test regions

Task 3.3.3: Climatic effects on Cultural Identity & Aesthetics

[no milestones foreseen for the time being]

Task 3.3.4: Relevance of the Social System for Cultural Identity & Aesthetics

Work will start with the joint analysis of the socio-cultural services as defined by the local stakeholders.

- **M 3.3.4.1 (2012 Feb):** Draft document on locally perceived ESS and their relative importance
- **M 3.3.4.2 (2012 May):** Draft document on the service providing units SPUs of socio-cultural and socio-economic services, as perceived by the service beneficiaries, and their potential links to provisioning and regulating services.

- **M 3.3.4.3 (2013 Feb):** Document on the specific social structures behind land use patterns, and their change with modernisation, urbanisation and migration, assessing also the feedback of these changes on the dynamics of land use change.
- **M 3.3.4.4 (2014 Feb)**: Qualitative assessment of future social structure changes under climate change scenarios, and their impact on local dynamics and land use and water level change.
- **M 3.3.4.5 (2015 Aug)**: Monitoring and evaluation of the socio-structural and economic impacts of the social learning experiments.

Work package number	**3.4**	**Summary across Tasks**				Start: 2012 Sep
Partner	UGR	PhilRice	IRRI (VSU)	UFZ	UMAR		
Personmonths (PM)	1	10	8	7	5		
Partner	UFZ (LUPO)	PIK	CEPSTA				TOTAL
Personmonths (PM)	2	2	1				36

Objectives

- To investigate and quantify the strength of functional links between land use, water management and biodiversity and their consequences for plant nutrition, productivity and species interaction between weeds and crop plants and mutualists (pollinators, biocontrol agents) and antagonists (insect pests, pathogens).
- To develop a conceptual framework on ecological interactions and feedback mechanisms between organisms with direct and indirect importance for ESF/ESS.
- To discuss monetary and non-monetary consequences of land use intensity induced changes of ESF/ESS caused by biodiversity changes.
- To estimate consequences of climate change on these relationships.
- To contribute to the development of region specific indicator systems for the ecological and economic evaluation of land use and water management strategies and provide suggestions for sustainable land use.
- To provide deeper insights and understanding of the importance of the investigated ecological processes to local people, farmers and decision makers.
- To ecologically evaluate prognoses on the impact of climate change on social systems and land use and water level changes.

Description of work

This WP will conceptually combine the results on the different experiments on the effects of land use changes on productivity and biodiversity, their feedback effects on essential ESF/ESS and the interplay with climatic factors and social structures. The combination of data on ecologically and economically important biotic interactions and their dependence on land use and water management traits will allow the identification of consequences of land used induced disruption of these interactions for productivity and sustainability of crop plant dominated systems. The results of the modelling approach in WP 3 on climate driven changes of social systems and land use strategies will be combined with data on corresponding changes in biodiversity and ESF/ESS.

Milestones (Results & Products)

- **M 3.4.1 (2015 Feb):** Draft document on recommendations for the implementation functional ecological indicators for region specific land use strategies, water management and sustainable land use.
- **M 3.4.2 (2015 Apr):** Draft document on concepts for the integration of results on the land use-biodiversity-ESF/ESS relationship in knowledge and decision making of local farmers and administration.
- **M 3.4.3 (2015 June):** Synthesis paper on a socio-economic view on biodiversity-ESF/ESS relationships in the different study regions in Europe and Asia and impacts of land use and water management change and climate change scenarios.

12.4 WP 4: Integration (across ESF/ESS strands)

Overall responsibility of WP 4: Kirsten Thonicke (PIK) in close cooperation with Joan Martinez Alier (UAB; Spain)

General aims of the WP: The conceptual linkage between the LEGATO work packages – across the ESF/ESS strands – is the main objective of WP 4, in which the core elements are 1) **Valuation**, 2) **Indicator Development**, 3) **Natural and Social Science Integration**, and 4) **Modelling** approaches for the creation of the larger picture under different scenarios of future development and the evaluation of ecological engineering activities. The cooperation in WP 4 demands a high degree of inter- and transdisciplinarity. The integration will be carried out mainly by developing and using an indicator framework, where data, modelling results and maps are joined to enable an interdisciplinary interpretation of the sub projects' outcomes. Also models and the scenarios they are illustrating are focal instruments of integration; the models will be used to quantify indicators, and the scenarios to link natural and social systems. In all instances ESS characterisations will be produced, which are transformed into socio-economic benefits and values. The interrelated results are developed in cooperation with stakeholders and will be used to improve decision making processes. For this purpose the produced methodologies and results of WP 4 will be focal dissemination products and they will be integrated into the LEGATO assessment tools.

Work package number	4.1	Valuation				Start: 2011 Sep
Partner	UAB / ICTA	UFZ					TOTAL
Personmonths PM)	10	4					14

Objectives

- To assess the value (monetary and non-monetary of the ecosystem services analysed in LEGATO
- To assess the risks to economically valuable service components (damage costs)
- To discuss the costs and benefits of ecological engineering (control costs, avoidance costs)
- To provide preliminary assessments of the cost of inaction for the agro-ecosystems under analysis
- To provide an assessment of non-monetary values affected by land use and climate changes, their ranking and policy relevance.

Description of work

The monetary valuation starts with the assessments of costs and gains (market value) of the current production pattern. As market values have been volatile, 2007, 2008 and 2009 market values will be taken into account, using local per hectare yields, the marketing structures (how much is part of domestic consumption, what is the share of exports). Domestic consumption is considered a non-market benefit, with no price but a price equivalent.

Then the total balance and the contributions of diverse ESS like soil formation, nutrient cycling and insect/parasite protection will be assessed, as far as the natural science research can provide a robust basis for such calculations. Essentially, each service generates a share of the value, so the total value calculated will be higher than the aggregated value of the individual services' contributions (as not all contributions are covered). Non-monetary values will be integrated but ordered according to lexicographic preferences instead of prices in order to take into account distributive issues and what has been called 'the GDP of the poor', i.e. livelihood value (TEEB, 2009).

On this basis, damage cost can be calculated for pest outbreaks, but also for climate, water supply and land use change (the social and economic costs of CC). For economic valuation, the damage cost is assessed as the loss of yield and its downstream impacts. The assessment of non-monetary values contributes details on the livelihood value and socio-cultural value and their changes involved in any policy option.

Data on damage costs, production profits and cost structure allow permitting the current situation with ecological engineering as an alternative, regarding expenditure and market gains, resource consumption and (data availability allowing) time budgets. This should include an assessment of the non-monetary costs of changes in landscape management.

Milestones (Results & Products)

- **M 4.1.1 (2012 Feb):** Draft inventory of values related to landscape and land (and water) use structures and patterns
- **M 4.1.2 (2013 Feb):** Draft document on the monetary and non-monetary value of the ESS analysed in LEGATO
- **M 4.1.3 (2014 Feb)** Preliminary estimate of the cost of inaction
- **M 4.1.4 (2015 Aug)** Economic balance of ecological engineering (assessing costs and gains, in terms of money, time - as far as data permit - and social change).

Work package number	**4.2**	**Indicators**					Start: 2011 Sep
Partner	CAU	UFZ	PIK				TOTAL
Personmonths PM)	38	8	5				51

Objectives

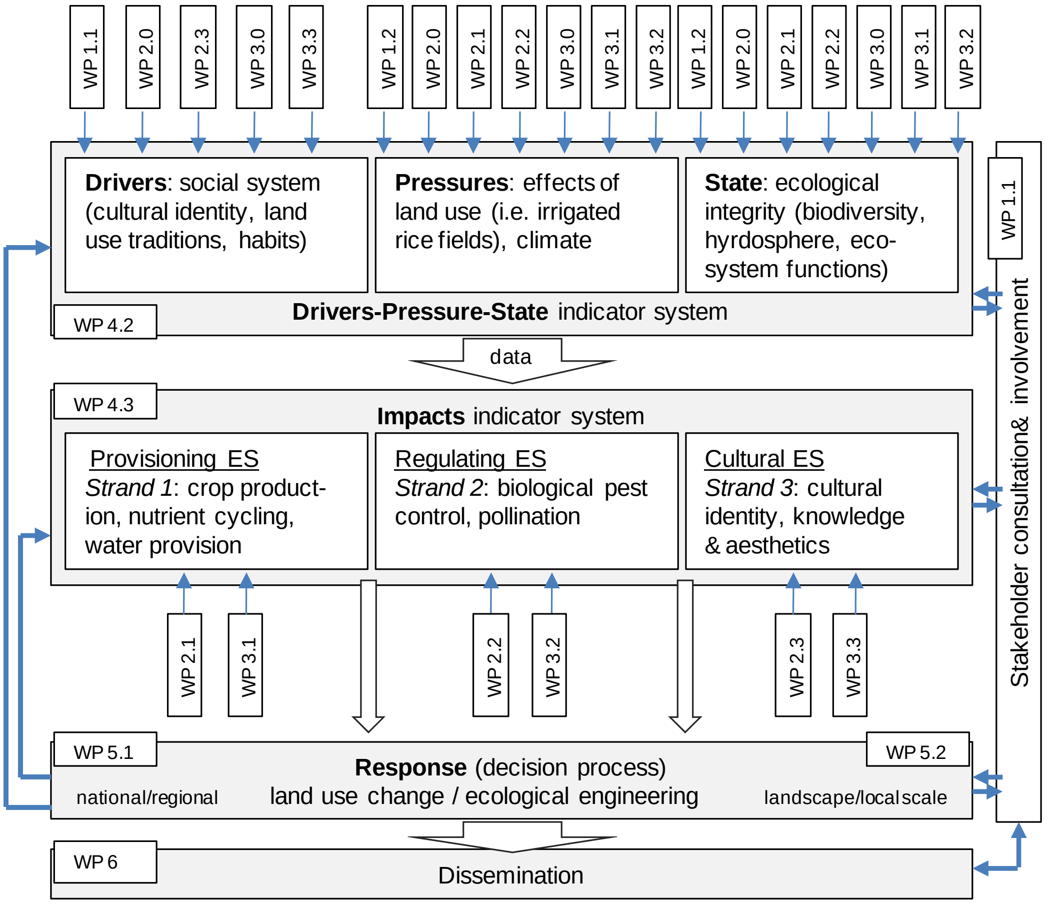
Overall:

- To identify suitable (feasible and effective) sets of indicators characterizing the state of the environment and related socio-economic and cultural factors on different scales and in different bio-geographic regions
- To quantify the indicators as far as appropriate based on results generated by the whole consortium.
- To play an integrating role within LEGATO by providing an integrative interdisciplinary **indicator framework system** which will be used by the project collaborators and which can be transferred into practice after the project works.

Indicators are extremely suitable tools of integration because they can be used to link theoretical approaches, observation results and experimental outcomes with practical applications. Indicators provide the focal information for decision making processes in land use management. They offer optimization variables to test the success of ecological engineering conceptions. Furthermore, indicators are utilized to combine social, economic and environmental items within one framework, focussing on the interrelations between the components. Consequently the LEGATO indicator system will function as a central interface between the different working groups and disciplines that are represented in the project. To fulfil that role, intensive feed backs with all project partners have to take place, the demands of the scientists have to be coupled with the requirements of the stakeholders, and the outcomes of all measuring activities in the project have to be adapted with the demands of the indicator network. This need for integration also means that the focal attributes of all work packages will be (i) assigned to one of the DPSIR indicator classes, (ii) related to the concept of ecosystem integrity, (iii) interlinked with potential influences on the investigated biodiversity components, and (iv) translated into the provisioning capacities for ecosystem services. These working steps as well as the planned assessment of resilience and adaptability are strictly dependent on a very high degree of communication with all project partners and a suitable, well-elaborated flow of data and information. Therefore, especially during the initial project phase, intensive

coordination activities will be carried out to guarantee an optimal degree of mutual adaptation. For this purpose, the acquainted and approved systems analytical procedures will be realized in workshops and bilateral discussions. As experience shows, the results of that joint development can hardly be planned in advance, i.e. due to the integration of local stakeholders and their special demands and preferences.
The constructive outcomes of these first working steps will be used to work on the specific targets of the work package 4.2.

The following figure demonstrates the information flow of WP 4.2 and 4.3 with the other working units of the project based on the DPSIR indicator approach.



Specific:

- To indicate the environmental state and the impact situation of the investigated landscapes and socio-economic components:

The regional comparisons will be carried out on the base of environmental (together with WPs 2.1, 2.1, 3.1., 3.2, 4.4) and socioeconomic (with WPs 2.3, 4.1, 4.3) characteristics which indicate the conditions and consequences of land use and its changes. In these indicator sets, **ecosystem services (ESS)** and their Service Providing Units SPUs will play a major role (as assessed by WP 4.3). They are also identified for the economic and socio-cultural ESS, and will include structural and functional indicators on the **biodiversity** situation (e.g. pollinators within Strand 2) and ecosystem processes and the socio-cultural drivers impacting on them (see figure below). For the physical aspects, the water, matter and energy budgets of the investigated landscapes will be characterized by captured inputs, losses, storage capacities, sink-source functions (e.g. of GHG) and ecosystem efficiency measures (**ecosystem integrity** indication to depict **ecosystem functions - ESF**). Recent work aiming at general indicator sets for biodiversity like the CBD indicators and the SEBI 2010 initiative of the European Environmental Agency (EEA) will be considered and as far as appropriate, adapted and if possible further developed. In particular the ecosystem management approach of the CBD will be taken into account as it combines biophysical components with livelihood aspects and their socio-cultural, economic and political conditions.

- **To characterise socio-ecological and socio-economic land use consequences:**

An important objective of the indicator framework is a coherent presentation of environmental, socio-cultural and economic issues in agro ecosystems and landscapes, indicating their interactions and some elements of the causation webs. For this purpose the **DPSIR** scheme (Burkhard & Müller 2008; see Figure 5.3 in chapter 5.1.1) will be modified, with a focus on biodiversity (see Binimelis et al. 2009) and ESS investigations.
The indicated components of this system will be external ***constraints*** (e.g. dynamics of climate, technology, legislation, policy), external and internal ***driving forces*** (socio-cultural and economic factors, e.g. motivations of the actors and economic activities), the resulting ***pressures*** on the environmental compartments (e.g. agriculture related environmental inputs), and their consequences, the changes in ecosystem ***state***, structure, function and integrity. These changes have ***impacts*** on environmental issues (ecosystem services) and human well-being. For an appropriate characterization of these components, the indicator derivation has to be closely integrated into the project activities in order to consider experience and expectations from the scientists as well the local people. The impacts will stimulate a management response (as changes of state, and insight into pressure mechanisms and their drivers will) which will cause a modification of policy approaches by triggering prevention, mitigation, restoration and/or adaptation strategies, closing and restarting the adaptive management cycle. The effects of human activities on provisioning services play an important role in the agro-ecosystems analysed in LEGATO. They will be assessed empirically by the socio-cultural and economic analyses. Theoretical analyses will be conducted e.g. by using modelling results from WP 4.4. (e.g. outputs from the LPJmL model which will be adapted to region-specific conditions following scenario evaluation in Task 1.2), an ecosystem service model of medium complexity, which acts as a link between complex ecosystem models like LPJml and indicators, and by calculating the 'Human Appropriation of Net Primary Production' (HANPP), an indicator of land-use intensity based on accounts of human-induced changes in trophic energy flows in ecosystems. HANPP takes two distinct processes into account: (a) changes in NPP resulting from land use as compared to the potential natural vegetation, and (b) extraction of biomass through harvest. Because NPP is a central parameter of ecosystem functioning, human-induced changes of NPP and its ecological pathways, and biomass extraction both affect ecosystem patterns, processes and functions. LEGATO will test the sensitivity of existing HANPP calculation methods and thus its suitability for assessing ecological engineering impacts. It furthermore will – if necessary – suggest modifications to the method, and will then test it by applying it in the comparative analysis between different sites in the same and similar sites in different countries.

As a result an interdisciplinary LEGATO indicator core set and a functional indicator framework will be established characterising the service providing units (SPU) behind different classes of ecosystem services. Practical implementations of the SPU concept are so far rather rare. SPUs should be quantified in terms of metrics such as abundance, phenology and distribution (Vandewalle et al. 2009). The integration of this concept into a large research consortium and its practical application in case study areas is promising. SPUs will be used to highlight the risks and opportunities of different production systems and to evaluate the consequences of land use regimes and their underlying development trajectories. The usability will be tested on the base of the LEGATO scenarios (WP 1.2) and the outcomes of the ecological engineering approach of LEGATO, integrating the bioscience and socio-cultural field site research results into the indicator framework.

- **To derive measures for resilience and adaptability**

The LEGATO scenarios will be calibrated using historical recordings and the results of experiments including varying land use intensities. In the scenarios, dependent on their respective assumptions, different temporal changes of the indicator values will appear. The correlation of conditions and indicator values will be used to find new methods and indications for the characterisation of ecological systems' behavioural potentials. The concepts of resilience and adaptability will be taken as starting points to measure the respective features of the SPUs, in particular of landscape-systems' development. Resilience and adaptability will also be relevant parameters analysed (as far as the available, mainly historical, data permit) in the socio-cultural analysis of the local communities, allowing for an integrated description of the socio-environmental system. This is an important precondition to identify appropriate management tools and policy instruments, which will be done in cooperation with WPs 5.1 and 5.2.

- **To adapt the indicators to different scales and carry out cross-site comparisons:**

Landscape processes operate on different spatio-temporal scales. To carry out the planned comparisons on intra-, trans- and superregional scales, the typical corresponding processes and interactions of different scales have to be taken into account. Therefore, the indicator derivation is based on feedback from the individual field and experimental assessment projects and the socio-cultural analysis. Thus, the indicator set will be adapted to available information, scale-specific processes and dominating constraints. For this purpose, a scaled indicator matrix (representing functional interrelations on different levels of extent and resolution) will be developed and applied for the site comparisons of LEGATO, as far the available data permit to do so. This matrix will be an important tool for all project participants as it gives metadata information on which data are available at which scale and resolution.

- **To implement the indicator framework**

The resulting indicator sets, the calculation rules and measurement methods, and the model routines for indicator derivation and the respective technical instruments for their practical application will be implemented into the "LEGATO Risk Assessment Tool (RAT)" and the indicator module of the "online toolkit" of the project. Furthermore, the indicator framework has to be strictly linked to the modelling approach of the project, making sure that the modelling outcomes can be easily related to the defined indicators. This will be carried out as an iterative process in a regular feedback loop between WP 4.2 and respective project strands.

Description of work

The main products of WP 4.2 will be the indicator framework system characterising the SPUs of the ESS under investigation, and a respective risk assessment strategy to evaluate agro-environmental dynamics, their socio-economic context, and ecological engineering concepts (risk is a social construct). These items will be based on regional distinctions in Geographic Information Systems that are linked with models and indicator calculation rules wherever appropriate. The results will be presented to stakeholders and landscape managers to gather their feedback regarding: a) the local relevance of the information collected, b) the appropriateness of the meaning constructed by interpretation of the data, and c) their potential usefulness for use in agricultural practice in social learning processes (see WP 3.3, and WP 1.1 "stakeholder consultations"). Eventually, this process may lead to modifications of the indicator selection and/or their interpretation in the regional context. These modified indicators ~~on the one hand,~~

~~and they~~ will be applied by members of the LEGATO team on the other (e.g. by WP 4.3 "social and natural science integration", WP 4.4 "modelling", WP 5 "Implementation" and 6 "Dissemination"). The Indicator Framework will be rather unique in its integration of ecological, social, cultural and economic factors, and will allow to highlight, in an integrated transdisciplinary fashion, the supply and demand basis of the ESS enjoyed by the service beneficiaries, the risks the SPUs are facing and the measures which can be taken, embedded in the socio-cultural context and thus probably effective, thus contributing to the LEGATO dissemination products "online tools" (WP 6.1) and the "risk assessment toolkit RAT" (WP 6.2).
To generate these products and to achieve the objectives of WP 4.2, besides a good coordination with WP 1.1 (stakeholder consultations) and WP 3.3. (socio-cultural experiments), an open data flow from WP 2 and 3, and a productive linkage to WP 4.4, the following working steps will be taken:

- **To indicate the environmental state and the impact situation of the investigated landscapes**

The work will start with literature studies and consultations with the LEGATO partners, the regional and local LEGATO stakeholders (WP 1.1; M 4.2.1) and international institutions that are working on agricultural indications and models (e.g. EEA, CBD, IUCN, FAO). As a first interim result the state-of-the-art will be documented in a review paper (D 4.2.1).
For the ESS under investigation in LEGATO, the Service Providing Units SPUs will be identified by the respective project partners, clarifying the definitions of services in the respective social context, and the role of biodiversity and landscape integrity for service provision (local peasants can have highly resonant indicators with the same ecosystem processes as *indicanda*, but expressed in a different 'language'. Such indicators, as far as available, will be documented in WP 4.4).
Based on this information suitable indicators will be selected for the dynamics of **biodiversity** as well as ecosystem and **landscape integrity**, which will be represented by features of the water, carbon, nutrient and energy budgets of the investigated agro ecosystem complexes. They will complement and be integrated with the economic and socio-cultural framework indicators to be developed in WP 4.1 and 3.3, respectively.
After a qualitative assessment of the investigated sites (M 4.2.2), which provides hypotheses on the state characterisation, the following indicators will be considered: Energy uptake (e.g. net primary production – application of the HANPP concept), energy loss (e.g. radiation balance, evapotranspiration, ecosystem respiration), storage capacity (e.g. N, P, soil organic matter, biomass), nutrient loss (e.g. nitrate leaching), ecosystem efficiency (e.g. biotic water flows, ratio production/biomass, ratio production/respiration), biodiversity and abiotic heterogeneity. These measures of integrity will be quantified based upon (i) the measured data of the LEGATO consortium, (ii) the new, regionally adapted results of the LPJmL model (PIK, WP 4.4) (iii) ecosystem services models of medium complexity using problem specific aggregations of modelling results (UFZ, WP 4.4) and established simulation programs which have been tested in several projects before (e.g. WASMOD; Reiche 1996). Using this toolset approach of complex ecosystem models, models of medium complexity and indicators we are able to derive indicators characterising the natural science component of SPUs of each strand in LEGATO. Complemented by the socio-cultural and economic analyses of the same sites, a comprehensive characterisation is expected to emerge. The HANPP data will, in addition, allow another integrative step in relating biophysical data to social structures and economic activities in the respective sites of analysis.
ESS will be represented in three steps: First of all, before the scientific analysis can take off, the services to be analysed must be defined in the local context (including stakeholder feedback). For starting the scientific analysis a recently developed qualitative method of ESS as-

sessment will be used (mainly based on land cover maps, deriving classifications for ESS based on indicators at the landscape level; see Burkhard et al. 2009) and the SPU of the ESS will be identified. The assessment concept will produce hypotheses for the provision of all services which have been applied throughout the Millennium Assessment project.
In the third step the indication will be based on quantitative algorithms. Prioritising the key indications of LEGATO (provisioning services: nutrient cycling & crop production; regulating services: biocontrol & pollination; cultural services: cultural identity & aesthetics) and their SPUs, **calculation rules and models** will be developed to derive the ESS estimates of the investigated socio-environmental systems (M 4.2.3). In this step there will be a close cooperation with WP 4.4 (modelling) and the empirical work packages of the project. Also official statistical information will be used for the quantification. The ESS models will be based on available model systems and data bases such as INVEST, ARIES, ECOVALUE, ENVALUE, EWRI, MIMES, and others. They must be applicable within the LEGATO data base, in good collaboration with WP 2 and 3.
The result of these two branches will be a **combined indicator module** representing the SPUs of focal ecosystem services and ecosystem integrity (M 4.2.7). While the integrity components will indicate the environmental state of the anthropogenically managed ecosystems, the service unit assessment will be used to indicate the impacts of different land use concepts (making also use of the socio-cultural and economic indicators) and external constraints (e.g. global climate change, technology, legislation, policy). Based on this integrated indicator module, an analysis of the synergies and trade-offs between different ecosystem services in a region becomes possible by comparing the impacts of the respective SPUs.

- **To characterise socio-ecological and socio-economic land use consequences**

While the first task predominantly provides ecological indicators, the integration into an overall framework will be carried out in task 4.2.2. Starting with a literature review (D 4.2.1) and consultations with project partners and stakeholders (WP 1.1, M 1.1.N.1) an adapted conceptual DPSIR indicator model will be developed (M 4.2.4, M 4.2.6, D 4.2.3). This scheme will include (quantitatively where possible) the dynamics of **systemic constraints** affecting the integrated indicator system. They include environmental dynamics (e.g. climate change variables provided by WPs 1.2, 4.4) as well as political frameworks (e.g. sustainability programs, agricultural policies WP 5.1), economic conditions (world market integration, prices, etc – WP 4.1), socio-cultural factors (motivation, readiness for change – WP 2.3) or technological (fertilizers, machines) and conceptual innovations (e.g. concepts of ecological engineering from the whole project). These factors have to be taken into account in scenario formulation as well which builds another feedback loop between WP 4.2 and further WPs.
The constraints influence the Driving Forces and Pressures within the system, mainly based on the motivations and opportunities of the local actors. The analysis of these **drivers** will be carried out mainly in cooperation with Module 3, where driver identification will play a major role.
As a result of the respective responses (prevention, mitigation, restoration and adaptation measures) certain land use structures and intensities will be realised which enact **pressures** on the respective ecosystems. In LEGATO the pressure indicators will mainly be directed towards agricultural activities. The linkage of the pressures and the changes in the ecosystem state as well as the consequences for SPU and consequently for ecosystem services have been described in task 1.
The subsequent indicator group is related to the **impacts** of modified pressures, states and services on **socio-economic and socio-cultural services**. Here social, cultural and economic indicators will be selected, focusing on the economic conditions, the socio-cultural implications of land use change and climate modification, the health situation and on factors of personal

and **environmental security, identity and well-being**. For these fields, several indicators exist, while others will be developed in the respective work packages of LEGATO, so that the main task will be a concentration and aggregation with reference to the specific LEGATO targets. These works will be done in collaboration with WP 4.3 and the socio-economic working groups of the project.
The DPSIR component **responses** will be investigated in a twofold way: on the one hand, problem solving responses will be identified based on the analysis of drivers, and will be compared with the responses planned or undertaken so far. The latter will be identified mainly by stakeholder interviews competent for the respective response strategies, in close cooperation with WP 1.1, WP 3 and WP 4.3. Problem solving responses can be identified by using the scenario assumptions as a starting point and evaluating (in the models) the results of the scenario actions. The trade-offs between different future options decision makers and stakeholders see and accept is another item to understand the response function. Experience from earlier work, including the EU projects SUSTRAT, PLUREL and RENMAN will be used to characterise these indicators.
It is expected that the number of **key indicators** in this framework can be reduced to 6-8 core variables per DPSIR component, which will mainly be selected due to (a) their suitability with respect to the overall framework, (b) their usefulness from the stakeholders' points of view, (c) the fit with the parameters used by the models involved, the response functions and the calculation rules and (d) data availability. Possible conflicts between the criteria will be solved in cooperation with the LEGATO partners. The technical implementation is a joint work with WP 4.3.5 (M 4.2.9) and the connection with the LEGATO modelling systems will be carried out in cooperation with WP 4.4 (M 4.2.3).

- **To derive measures for resilience and adaptability**

The indicator framework will be tested for its representation of the ecosystem dynamics and its socio-economic context by (a) comparing the outcomes with the **LEGATO site data** and **historical data sets** for these sites to adapt the framework and to improve the results. In a next step (b) the indicators will be used to summarise the outcomes of the **LEGATO scenarios** (D 4.2.4) and a third application (c) will be related to an evaluation and – where appropriate and possible – an optimisation of the **ecological engineering** approaches of the project (D 4.2.5). In this case study, the targets and characteristics of ecological engineering after Mitsch and Joergensen (2004) will be used in connection with the empirical experience in the test region and the integrity indicators to derive a theoretically optimal engineering strategy, validate it by comparison with the empirical evidence and the resonance of stakeholders, and to test the outcomes against the theoretical expectations which are based on different ecosystem theories (e.g. orientor approach and ecosystem thermodynamics; Müller & Leupelt 1998). The socio-economic and socio-cultural results of a transition towards ecological engineering and their relation to the change in ecosystem service provision will be analysed, where adequate and possible quantified, and potential trade-offs between services will be collectively evaluated
To characterise the dynamics of these three applications, the concepts of resilience and adaptability will be reviewed (D 4.2.2), tested and further developed for the analysis of ecological (on a landscape scale as far as appropriate) and socio-cultural systems. Based on a recent revision of the concepts (Müller et al 2010), **resilience** refers to the ability of a system to reorganise after a disturbance and remain in the previous attractor basin. In contrast, a system has a high **adaptability** if the sum of all disturbances and changes in the attractor domains do not reduce the system's capability of self-organisation. This means that the system will follow complexifying dynamics and optimise focal orientor functions, which are represented by the integrity indicators from WP 4.2.1 (for social and economic orientor functions see e.g. Spangenberg 2005). To assess resilience and adaptability with the ecological indicators of the larg-

er system, time series related measures derived from the project case studies' results, will be applied. Moreover, local stakeholders will be involved in order to include their opinions and strategies regarding adaptive management.

- **To adapt the indicators to different scales and carry out cross-site comparisons**

The ecological LEGATO analyses will be carried out at different scales, e.g. at the site scale, the regional scale of the surrounding landscape and a supra-regional scale. The socio-cultural analysis has to deal with anthropogenically defined scales to be identified in the pre-test in WP 3.3. Therefore, the indicator framework has to be adapted to the data from the assessments which are very distinct in quality and quantity and which have to fulfil certain practical and thematic requirements. Furthermore e.g. social and economic data very often are only available at the municipality scale while the environmental results often are worked out on smaller plots. Thus **cross-scale functions** for indicator calculation must be worked out, and in several cases **upscaling and downscaling procedures** must be developed for the highly structured agricultural landscapes to represent the project results with common spatio-temporal resolutions and extents. Here, an interaction and several feedback-loops with respective data providers from the WPs will take place in order to safeguard an appropriate representation of phenomena in focus. Furthermore, it can be expected that some variables can be applied on certain scales only and that others are not available in all resolutions.
To ensure a correct scaling procedure and to investigate the scale-specific restrictions, **indicator matrices** (showing interrelations between all indicators and the necessary input and output variables) will be developed for all relevant project extents. The outcome will be used to adapt the indicator framework to the requirements of the working scales of the project. The resulting variable sets will be typically characterised by a potential loss of information and to the potentially related uncertainties of the outputs (M 4.2.5). These restrictions will be tested by **cross-site comparisons**, involving all relevant project partners**.**

- **Technical implementation of the indicator framework**

To use the indicator framework successfully within the LEGATO project and to make it applicable for stakeholders, it is necessary to present it to adapt it, and its presentation, to the needs and recommendations of different stakeholders. In particular for higher level land use planners it will be important to develop a technical environment, which consists of linkages of the indicators with geographic information systems (GIS), with the models applied and developed, the indicator derivation rules and the LEGATO data base (M 4.2.8).
Furthermore, the indicator modules have to be implemented within the LEGATO "**Risk Assessment Tool**" (RAT, WP 6.2) and the LEGATO **online toolkit** (WP 6.1). The respective works will be carried out in close cooperation with the responsible work packages 6.1 and 6.2.
Additionally the indicator framework must be **documented** and the single indicators must be characterised by **indicator fact sheets** (D 4.2.6).
These dissemination related works are prepared by stakeholder consultations (WP 1.1; M 1.1.N.2). The consultation result will be the basis of a revision of the system and its presentation to enhance its understandability, applicability and the technical usefulness. Understanding is also enhanced by developing easily understandable written information material including guidelines for stakeholders and decision makers (WP 6.3), and application will be supported by offering a training course (WP 7.3).

Milestones (Results & Products)

- **M 4.2.1 (2011 Dec):** Literature review on applied indicator frameworks
- **M 4.2.2 (2011 Dec):** Report on conceptual guidelines after stakeholder and partner consultations
- **M 4.2.3 (2012 Feb):** Report on the qualitative assessment of integrity and ecosystem services (Hypothesis paper and maps)
- **M 4.2.4 (2012 May):** Strategy paper on indicator-model-linkages (with WP 4.4)
- **M 4.2.5 (2012 June):** Literature review on applied resilience and adaptability concepts
- **M 4.2.6 (2012 June):** Documentation of the key indicator set proposal
- **M 4.2.7 (2013 Feb):** Preliminary report on the draft indicator framework
- **M 4.2.8 (2012 Aug):** Documentation of indicator scale matrices
- **M 4.2.9 (2013 June):** Workshop on results for ESS and integrity indicators
- **M 4.2.10 (2013 Nov):** Workshop on results for DPSIR components
- **M 4.2.11 (2014 Feb):** Report on the developed indicator framework concept and prototype
- **M 4.2.12 (2014 Aug):** Documentation of scenario calculation results (Resilience and adaptability of LEGATO indicators)
- **M 4.2.13 (2014 Oct):** Documentation on ecological engineering results
- **M 4.2.14 (2014 Oct):** Technical implementation in RAT and online toolkit
- **M 4.2.15 (2015 Feb):** Documentation of concepts, tools and results incl. indicator fact sheets

Work package number	**4.3**	**Comprehensive ESS Assessment**				Start: 2011 Sep	
Partner	UFZ	CAU	UMAR	IEBR	UGOE		TOTAL
Personmonths (PM)	17	6	5	2	1		31

Objectives

The integration of human and natural sciences is a task which will be conducted continuously throughout the whole project duration, and in all WPs. All participating teams will clearly define the specific ecosystem services in the respective social and ecological context they are analysing, beginning with the stakeholder interviews in WP 1.1. Based on objective criteria for the natural science analysis (but embedded in a social context), on the subjective assessment of stakeholders for the socio-cultural science analysis (but informed by the bioscience analyses), plus the market values and the non-market valuation for the economic analysis in WP 4.1, it will be possible to draw an integrated picture. For the latter two analyses, after delineating the services, the service beneficiaries who defined what is perceived as a service will be asked to identify the source of the respective services, i.e. reveal their identification of the relevant Service Providing Units SPUs. This may be the landscape as a whole, or a cultural context including the landscape, but also certain elements or subunits of the landscape.
The resulting preliminary mapping of socio-culturally constructed ecosystem services and the perceived SPUs over the landscape allows for comparison with spatial structures, habitat types or bio-geochemical traits, in particular with those identified as SPUs in the causation web analyses in WP 4.2 for the provisioning and the regulating ESS in order to again generate

an integrative description. The identification of similar and/or diverging delineations is a crucial condition for the communication and later implementation of the results of the scientific analysis.
Some focal inputs to these discussions will be based on the basic DPSIR indicator model (see WP 4.2) which provides a heuristic structuring device for the relationships between the human and environmental subsystems. We are aware that DPSIR is no analytical scheme and cannot guide the research to be undertaken, but is a convenient and tested means for presenting the results of such research (Maxim et al. 2009). These archetypical linkages will be substantiated and/or replaced by the empirically detected mechanisms on the basis of the LEGATO field assessments and experiments (WP 2 and 3). As the linkages between the different subsystems are also basic features of sustainability management, the sustainability relevance of the interaction analysis will be enhanced by applying the so-called Malawi principles of the CBD. The discussion of scenario outcomes will be based on these ideas and will feed into WP 6.
A fourth aspect will be related to the diminishing spatial coincidence of ecosystem services and the human well-being they contribute to: as a consequence of globalisation the environmental and social impacts related e.g. to the provision of food, fodder and fuel are spatially disconnected from the consumption side. Therefore, either the concept of the ecological footprint (modified as appropriate given the local conditions and data availability) or the calculation of HANPP (from WP 4.2) allocated if possible per service will be regionally adapted to the ratio of ecosystem service provision vs. demand (production based vs. consumption based calculation). Summarizing, there are three main objectives:

- To investigate the linkages between the different ESS and their provision basis (SPUs) in natural and human systems, i.e. the pressures on land use and their effects, and the interrelations of ecosystem services and human wellbeing by social and natural science means.
- To derive suggestions for an optimal land use management structure with reference to the 12 principles of the CBD ecosystem management approach (contributing to the model component “response”) as a basis for discussion with local stakeholders (to be revised afterwards).
- To develop an ecosystem service foot print/HANPP assessment with special reference to the provisioning service food production.

Description of work

The interdisciplinary linkages can be analysed only in interdisciplinary collaboration. Therefore, a well-suited cooperation between social systems analysis of strands 1 to 3 from WP 2 and 3 is planned as well as with WP 4.1 (Valuation), WP 4.2 (Indicators) and WP 4.4 (Modelling). Besides the continuous communication and cooperation, the following tasks are planned:

- **Investigating existing linkages within the indicator framework concept model (Pressure →State, Impact→Well-being)**

This work will be based on the elaborated indicator framework from WP 4.2. The linkages between human and environmental systems are part of that system. In particular we will analyse the effects of anthropogenic land use activities (pressures) on ecosystem integrity (state) as defined in WP 4.2. Furthermore, we will investigate the relation between the ecosystem services provided and perceived (WPs 1.1.) and human well-being as analysed in WP 2.3 and 3.3 and present the results in form of the DPSIR scheme. Especially in the latter context, spatial disconnections between service generation and service consumption (and thus the shifting defini-

tion of services and ESS beneficiaries) still provide conceptual challenges.
Within this task the interrelations will be analysed by an interdisciplinary team, using the field assessment and experimental data to explore some key effect mechanisms and their corresponding response functions. For this purpose, the results of a workshop with ecologists, economists, regional and local stakeholders and social scientists will be documented. In this document also the challenges of inter- resp. transdisciplinarity will be analysed and concepts to cope with those problems will be worked out (M4.3.2).

- **Applying the CBD/IUCN ecosystem management approach**

The CBD ecosystem management approach as developed by IUCN and its Commission on Ecosystem management includes well-elaborated and challenging requirements. Besides the operational guidelines the 12 ecosystem management principles provide a good framework for a comparative analysis of the existing management layouts and their inherent transdisciplinarity in the case study regions and the hypothetical optimal management systems derived in WP 4.2 to the general CBD principles. The joint analysis (to which project partners from all relevant disciplines will be invited) will further develop the proposals for an adaptive management structure developed in WP 4.2, based on ESF and ESS conservation and optimisation (M 4.3.1) and here combined with social, livelihood and structural criteria.

- **Developing an ecosystem service footprint/HANPP per service analysis**

Recent research has shown that in particular the interaction between ecosystem service provision, land use related service reductions and service demands is characterised by a decoupling process which gets stronger with the development stage of the investigated area. The LEGATO test sites differ regarding their development stage and their food & feed trade balances, which constitutes another gradient in addition to the biophysical and socio-cultural ones already described.
Globalisation processes have led to an intercontinental exchange of goods including food, feed, fuel and fibres, and a significant delivery of food and in particular feed from South to North on a global scale. On a national scale, our target countries are partly net exports, partly importers of food. On a regional or local scale, this may be different again – there are deficit regions in surplus countries and vice versa. In either case, the environmental damages (ecosystem disservices) are de-localised from the service providing units of the provisioning service “grain yield“.
To demonstrate a respective range of these conditions, the LEGATO case study regions will be analysed to depict the ratio of yield as a provisioning service and local grain consumption. Both consumption and export (domestic or international) contribute to livelihoods, by providing food and income, respectively. However, calculating the ecological footprint/HANPP per service (see WP 4.2) of the regions, the results will differ if only local service consumption or also export is taken into account. Thus the individual sites have to be checked individually for their respective trade balance (using data from WP 4.1 and complementing them). Also this task has to be carried out in a team of interdisciplinary character (M 4.3.2).

Milestones (Results & Products)

- **M 4.3.1 (2013 Feb):** Comparative documentation of the human-environmental interaction *types* in the case study areas on the basis of data gathered earlier WPs, using the CBD/IUCN ecosystem management principles.
- **M.4.3.2 (2014 Feb):** Workshop on response functions between the elements of the model components Pressure – State and Impact – Human well-being
- **M 4.3.3 (2015 Feb):** Joint scientific paper on ecosystem service footprints/HANPP analysis

Work package number	**4.4**	**Modelling**				Start: 2011 Sep
Partner	PIK	UFZ	IEBR			TOTAL
Personmonths (PM)	19	11	5			35

Objectives

- To quantify impacts of the surrounding (semi-)natural landscape structure on agricultural production across spatial scales based on findings from WP 2 and WP 3
- To evaluate changes in agricultural production as a result of climate (incl. water supply) and land use changes
- To characterize the role of ecosystem services and functioning in close collaboration with the indicator framework in WP 4.2

Description of work

This WP will look at the effects of surrounding landscapes on agricultural production. It will integrate the findings of WP2 and WP3 on impacts of land use intensity, biodiversity and climate on Strand A (Provisioning Services) and Strand B (Regulating Services) in a modeling framework to allow for scenario analyses and quantitative assessments. This framework will build upon an existing model of terrestrial ecosystem dynamics (LPJmL, Sitch et al. 2003, Bondeau et al. 2007), which is considered the most widely tested and applied model of its kind. LPJmL uses basic process descriptions about the relation between atmospheric conditions, soils, and land use, to derive a functional description of (a) (semi-)natural ecosystem structure including many characteristics of relevance to ecosystem service provision, and (b) agricultural systems including crop production. The main advantage of this approach, compared to others is that multiple scenarios for changing CO2, climate and land use can be investigated with high consistency.

However, important feedbacks between (semi-)natural ecosystems, i.e. the surrounding landscape, and agricultural systems can currently not be addressed by LPJmL. These feedbacks include provisioning as well as regulating services. The major task of this work package will therefore be the integration of these feedbacks into LPJmL, based on findings in WP 2 and WP 3, as well as on the stakeholder dialogue in WP 1.1. Specifically, LPJmL will be extended via response functions of crop production on characteristics of the surrounding landscape (incl. water provision). This provides a step to link regulating and provisioning services of (semi-) natural ecosystems to ecosystem services of agricultural systems. Examples for these response functions could be the beneficial effects of the surrounding landscape on the water and nutrient balance of agricultural systems, or on increases in crop production by provision of habitat for pollinators. For the water budget modelling WASMOD will be used based on input data from WPs 2 and 3. In this context, a close collaboration with the indicator framework in WP 4.2 is essential, to integrate the findings of WP 2 and WP 3 consistently. An important step will also be the adaptation of LPJmL and WASMOD to local conditions. Land use changes resulting from socio-economic scenarios provided by the coordination project GLUES will be adapted to meet regional specific requirements.

The evaluation of LPJmL results will then allow for an assessment of how agricultural production responds to ecological engineering effects of the surrounding landscape, a set of land use scenarios and therefore a changing surrounding landscape including its biodiversity, and future climate conditions and their direct and indirect effects on crop production (incl. impacts of changes in water supplies).

Particularly, trade-offs between the extension of agricultural areas to increase agricultural production on the one hand, and the involved reduction of ecological engineering effects of the surrounding landscape on the other hand, can be assessed in this framework (similar to an analysis performed by Nelson et al. 2009 for Oregon, USA). For linking up these results based on complex and highly integrated ecosystem models, an aggregate model for ecosystem services of medium complexity can be derived that suites the requirement of an indicator development and helps to assess underlying uncertainties. Additionally, this supports the analysis of trade-offs to optimize ecosystem service provisioning.
Additionally, it will be assessed, whether ecological engineering effects of the surrounding landscape can offer buffer mechanisms for a stable crop production in the light of climate change.
These assessments will be conducted on various spatial scales, ranging from regional analyses to different bio-geographic regions.

Milestones (Results & Products)

- **M 4.4.1 (2014 June):** Agreement with stakeholders and local experts on feedbacks between surrounding landscape and agricultural systems
- **M 4.4.2 (2014 Aug):** Summary of feedbacks between surrounding landscape and agricultural systems which will be considered in modeling framework
- **M 4.4.3 (2014 Dec):** Results of Water budget modelling based on WASMOD
- **M 4.4.4 (2014 Dec):** Implementation of feedbacks in LPJmL and analysis of the role of feedback mechanisms for agricultural production (incl. water provision)
- **M 4.4.5 (2014 Dec):** Analysis of the impacts of land use intensification, biodiversity, and climate across scales
- **M 4.4.6 (2015 Feb):** Documentation of impacts of land use intensification, biodiversity, and climate across scales
- **M 4.4.7 (2015 Aug):** Analysis of the impacts climate change and potential buffer mechanisms of the surrounding landscape on agricultural production
- **M 4.4.8 (2015 Oct):** Documentation of impacts climate change and potential buffer mechanisms of the surrounding landscape on agricultural production

12.5 WP 5: Implementation

Overall responsibility of WP 5: Kong Luen Heong (IRRI; Philippines) in close cooperation with Mohd Norowi Hamid (MARDI; Malaysia).

General aims of the WP: Based on the results of WPs 2-4 recommendations for implementation of ecological engineering will be elaborated and tested within WP 5. Thus, the application of the results in real agricultural systems is of particular importance and the main aim of the WP as well as of the entire LEGATO project.

Work package number	**5.1**	**National & regional implementation** (Policies & Data Provision from and to Stakeholders)				Start: 2013 March	
Partner	IRRI	UFZ	IEBR	IRRI (MARD)	MARDI	UGR	
Personmonths PM)	10	8	6	5	5	5	
Partner	S4U	IRRI (VSU)	UAB / ICTA	CABI			TOTAL
Personmonths PM)	5	3	3	2			52

Objectives

- To provide guidelines for sustainable farming practices, conserving biodiversity, reducing pesticide impact, guaranteeing water provision and maximizing production
- To provide national research partners with an analytical framework and tools to monitoring of impact of agricultural practices and climate change on rice based systems
- To evaluate on-farm practices in conserving biodiversity, reducing pesticides impacts and maximising productivity with participation with farmers.
- To conduct policy dialogues with high level officials in project pilot sites to facilitate implementation of biodiversity conservation techniques and policy adjustments.

Description of work

This WP will focus on implementing the recommendations and practices developed by other WPs in the project to conserve biodiversity and maximise production. The main stakeholders involved in implementing the sustainable practices will include farmers, extension, local governments, policy makers and NGOs. Adopting multi stakeholder consultations will enhance implementation success. Work will be presented by the following steps:

- Integrate the findings from WPs in the project into key guidelines, recommendations and on-farm practices.
- Conduct knowledge, attitude and practice (KAP) surveys of stakeholders to understand main constraints towards the key guidelines and practices.
- Conduct on-farm evaluations of key practices with farmer participation in pilot sites.
- Analyse related policies regarding biodiversity conservation and agriculture in the key sites.

- Conduct policy dialogues with stakeholders involved in policy implementations to facilitate policy adjustments to favour implementation.

Milestones (Results & Products)

- **M 5.1.1 (2014 Jan):** Draft document: Recommendations for agricultural practices for sustainable management
- **M 5.1.2 (2014 Feb):** Draft manual of analytical framework and tools for assessing impact of agricultural (incl. water management) practices and climate change on rice based ecosystems
- **M 5.1.3 (2012 Feb):** Report on farmers' KAP in conservation practices
- **M 5.1.4 (2013 Aug):** Report on farmers' evaluation of key conservation practices.
- **M 5.1.5 (2014 Feb):** Report on policies related to conservation and agriculture in the pilot sites
- **M 5.1.6 (2014 Feb):** Report on the policy dialogues conducted in key implementation sites.

Work package number	**5.2**	**Landscape Level & Local Implementation (Ecol. Engin.)**			Start: 2013 Mar	
Partner	IEBR	MARD	MARDI	UGOE	S4U	CABI	
Personmonths PM)	16	14	7	5	5	5	
Partner	VSU	UGR	UFZ	CEPSTA	IRRI		TOTAL
Personmonths PM)	4	4	2	2	2		65

Objectives

- To implement newly developed land use strategies with local farmers

Description of work

The implementation of LEGATO based and newly developed agricultural systems and land use strategies on farmers' fields is planned to be achieved with an emphasis on ecological engineering [avoidance of nutrient loss (possibly linked with efficient water use) and integrated pest management, etc.] to contribute to the adaptation of cropping systems to climate change.

Throughout this project activity (ca. 2013 March 2015 Feb) continuous evaluation of the biotic and abiotic ESF and ESS of the experimentally modified or statistically deducted land use practices will be conducted jointly by researchers and stakeholders (particularly the farmers involved). Criteria for evaluation are the improvements of the land use systems under scenarios of climate change.

Permanent exchange with representatives of the AoIs on the ecological engineering field experiments for comparative evaluation with the aim of mutual gains and cropping system improvements.

Conducting interviews with farmers and farming enterprises on their experiences with the implementation of recommendations (positive and problematic elements, etc.).

Milestones (Results & Products)

- **M 5.2.1 (2014 Feb):** Draft document on impact of agricultural (incl. water management) practices and climate on biodiversity and ecosystem services in key sites
- **M 5.2.2 (2015 Feb):** Report on implementation of ecological engineering strategies showing the degree of already achieved implementation.
- **M 5.2.3 (2016 Feb):** Report on prospects of ecological engineering as baseline for extension services. This concluding report elaborates the options of sustainable and durable future application of the jointly developed climate change adapted agricultural and land-use (ecological engineering) strategies for the AoI of Saxony. The report elaborates in detail on the main measures which should be implemented on a larger scale.

12.6 WP 6: Dissemination

Overall responsibility of WP 6: Lyubomir Penev (PENSOFT; Bulgaria) in close cooperation with Norbert Hirneisen (S4Y)

General aims of the WP: This work package will use different communication channels to interact with the population in the research areas, inform on the ongoing project and publish results. This will be done using the classical approach by printed publication (books, proceedings, information leaflets, folders etc.) as well as by internet.

In view of the increasing numbers of mobile devices several applications in connection with citizen science will be available as mobile services as well (identification aides and online recording of observations). All interested parties will be informed on events within the project using the Twitter service.

Interaction between the population in the research areas and the project will be crucial to the data gathering aspects for species occurrences (WP 6.1). Together with WP 2.3 and WP 7 several campaigns will be launched to involve the population. An online-community for species observation supported by species fact sheets, discussion boards, identification aides and picture upload will provide several levels of interaction and will help to get access to the interested public. The communication of scientific results and the collaboration within the project and from and to the stakeholders will be addressed in WP 6.3. The results of key parts of this project will culminate in the Risk Assessment Toolkit (RAT) of WP 6.2 where a web based easy-to-use application will make data and results freely accessible.

Work package number	**6.1**	**Online Tools for active participation**				Start: 2011 March	
Partner	UFZ (S4U)	PENSOFT	CABI	UFZ (LUPO)	S4y		TOTAL
Personmonths PM)	30	10	6	3	3		52

Objectives

- To involve the general public in the research areas in data gathering (citizen science) using a multi-channel interactive approach (print, web, mobile services).
- To give the general public a better understanding of selected species groups important to the research area.
- To transfer knowledge and improve the communication between project scientists, stakeholders and the general public (in close cooperation with WP 6.3).
- To organize campaigns to get the public involved and to motivate people in contributing observations and knowledge on local biodiversity (in close cooperation with WP 2.3).
- To assist other work packages on IT-issues (e.g., database design, webserver administration, web security issues) and data converting problems.

Description of work

The WP consists of three tasks, namely IT-Services and online community, Species information and easy-to-use identification aids, and PR campaigns for citizen science.

The first task will deal with the design and implementation of a web based online community and with IT-services for other WPs (e.g., 6.2, 6.3, 2.3). The second part will cover dissemination of the species to be selected for the involvement of local citizen scientists. This includes compiling information on the selected species (fact sheets, pictures) and developing easy-to-use (easy as by general public) identification aids. This will be done in close cooperation with WP 2.3.

In the third task we have to ensure that the tools and products of tasks 6.1.1 and 6.1.2 will be put to good use. Therefore we will start some PR work, preferably in cooperation with local newspapers, websites and radio or television companies in the AoI.

Task 6.1.1: IT-Services and online community

We will implement various web-based community projects addressing nature observation by the general public. We will make use of an Oracle-backed web-application based on the open source framework JAVA-struts which has already been developed by science4you. The application is multi-tenant and supports customization. Basic components are discussion boards, picture upload, identification aides, species fact sheets with integrated content management system, distribution maps generation on-the-flay and by nightly builds, activity diagrams and data management for the individual recordings of the users.

First, the basic web infrastructure will be in place consisting of an application server running Apache 2.x and Tomcat 6.x on Linux with connection to a database server running Oracle 11. Additional services will be a subversion server for source code management and a buglist system based on Trac. These services will be available to all project members. System availability will be secured by using server monitoring software (Munin, Nagios) and a system administrator on standby.

Then the basic science4you application will be implemented and adapted to the research areas, their species lists and individual maps. Each country (Philippines, Vietnam, Malaysia) will be a subproject on its own and has to be localized to the languages used in the area - particularly in Vietnam (while in our research areas in the Philippines and in Malaysia practically everybody speaks English). The basic common language will be English. An English version will hence be available in all subprojects. In addition the subprojects have to be adapted to meet the requirements of local laws (imprint, data security, disclaimers). During the test phase the content will be completed (species fact sheets, identification aides in corporation with WP 2.3.2 a.o.) and the application goes through optimization. This will be accompanied by distribution of easy-to-use identification aides as printed folders suitable for outdoor use and as iPhone and Ipod applications. This will be followed by a similar application for mobile devices running Android. Furthermore, a webservice will be launched to interact with the mobile devices. User will be able to send observations and pictures to the webserver and will receive updated information on species distribution and recent sightings based on their recent location (location based services).

For each country and species group a moderator will be needed to assist in communication (discussion board, email, phone) with the laymen and to improve data quality. The moderators can be located everywhere where a fast internet connection is available. Based on the experiences on German online recording communities the workload can be calculated being about 1-2 hours a day.

For each region 3 moderators are needed and are planned to be supported by LEGATO. One of them is also responsible for general questions. The local moderators will be supported by the South-East-Asian information centre located at CABI in Malaysia where a half-time coordinator will be installed.

At this stage user support is most important and will be guaranteed. Lastly, we will start collating data from our own and other free available biodiversity data collections (in close cooperation with WP 6.2). In support of other work packages we will start data mining and help with data converting and building data interfaces.

Task 6.1.2: Species information and easy-to-use identification aides

Selected plants, bees, dragon- and damselflies are components of our preliminary species list to be watched out by volunteers of the local communities (citizen scientists). For each region we will compile the list and we will add species fact sheets for each species. The species list will be completed based on the results of WP 2.3.2 (important local species, neophytes, widely known species …). Common names will be an important issue and the fact sheets will be compiled in English and in the most common local language.

As soon as possible we will start designing easy-to-use identification guides based on simple drawings, pictures and symbols. If species are difficult to distinct we will use species groups. The main target is to involve as many members of the general public as possible in our citizen science scheme. The identification guides will be available as printed folders suitable for outdoor use, on the website and as iPhone, iPod Touch and Android application. One year after the launch of the final application we will re-evaluate the species list and will make adaptations if necessary.

Task 6.1.3: PR campaigns for citizen science

In close cooperation with WP 2.3, WP 6.3 and WP 7 a PR strategy will be prepared. Involving local newspapers, radio and TV-stations and websites, we will report on the project and present the interactive web application and the mobile services. This will be supported by a picture contest where stakeholders could be integrated as jury. Three PR events will occur annually after the 2nd year.

Milestones (Results & Products)

Task 6.1.1: IT-Services and online

- **M 6.1.1.1 (2011 Aug):** Setting up IT infrastructure.
- **M 6.1.1.2 (2012 Feb):** Launch prototype of online community interface.
- **M 6.1.1.3 (2013 Feb):** Launch final version of online community interface.
- **M 6.1.1.4 (2013 Aug):** Webservice for handling observation data via mobile devices will be online.
- **M 6.1.1.5 (2014 Aug):** Integration of other biodiversity data sources will be finished.
- **M 6.1.1.6 (2015 Feb):** Interfaces and data mining for other project partners will be available.
- **M 6.1.1.7 (2016 Feb):** Report on IT infrastructure.

Task 6.1.2: Species information and easy-to-use identification aids

- **M 6.1.2.1 (2011 Aug):** Draft of preliminary species list will be available.
- **M 6.1.2.2 (2012 Feb):** Compilation of preliminary species list will be finished.
- **M 6.1.2.3 (2012 Aug):** Species fact sheets will be added.
- **M 6.1.2.4 (2013 Feb):** Identification aids for dragonflies online, print, iPhone will be available.
- **M 6.1.2.5 (2013 Aug):** Identification aids for Android will be available.
- **M 6.1.2.6 (2014 Feb):** Adaptation of selected species list will be finished.
- **M 6.1.1.7 (2016 Feb):** Report on identification aids for citizen scientist involvement.

Task 6.1.3: PR campaigns for citizen science

- **M 6.1.3.1 (2012 Feb)** Draft for PR campaign will be finished.
- **M 6.1.3.2 (2013 Feb)** Launch of campaigns in the research areas.
- **M 6.1.3.3 (2014 Feb)** Launch of campaigns in the research areas.
- **M 6.1.3.4 (2015 Feb)** Launch of campaigns in the research areas.
- **M 6.1.3.5 (2016 Feb)** Report on PR campaigns for citizen science.

Work package number	**6.2**	**RAT (Risk Assessment Toolkit)**				Start: 2011 March	
Partner	UFZ (OLAN)	OLANIS	IEBR	PENSOFT	BIOSS	CABI	TOTAL
Personmonths PM)	30	12	10	10	9	3	73

Objectives

- Development a web-based Ecosystem services Risk Assessment Toolkit (RAT) designed to disseminate key outputs of the project.
- Provision of quantitative support to some of the key scientific aspects of the project via the development of mathematical process-based models and statistical analysis of ESF/ESS (incl. quantification and communication of uncertainty)

Description of work

The RAT will take the form of a web-portal providing access to a database of results and methods for the characterisation and assessment of ESF/ESS risks and opportunities, due to changes in land-use, biodiversity and climate, developed throughout this project. A key part of this work will be a focus on integrative and cross-cutting issues ensuring that this tool provides access to the most policy relevant information derived from the scientific studies carried out within LEGATO, in a manner which appropriately reflects the uncertainty described above. This strand of work builds on the experience of the research team who previously developed a similar tool for risk assessments for European Biodiversity under the EU FP6 IP ALARM. To successfully achieve these goals will require interaction between the project consortium and stakeholders in order match scientific knowledge with stakeholder requirements. Therefore mid-way through the project one of the key stages of this process will be to seek stakeholder feedback on a prototype RAT providing access to preliminary results from the project.

Mathematical models and statistical analyses will be developed in support of and in collaboration with other scientific teams within LEGATO, adding to the cross-cutting and integrative nature of this work package. Since a key requirement for the success of such quantitative approaches is the availability of both scientific knowledge and appropriate data, both of which will evolve during the project, the precise nature of these collaborations will also be refined during the project. Moreover, since a complete understanding of all aspects of ESF/ESS is beyond the scope of the current project, the focus will be on developing case studies (e.g. initially focussing on bio-control of crop pests as a regulating service, although focus may shift to more appropriate examples) to better understand key issues such as the statistical properties of indicators of ecosystem services, and the interaction between landscape heterogeneity, biodiversity and ecosystem services. An important aspect of this work will be the quantification and communication of uncertainty in our ability to assess Ecosystem functions, services and resilience, since this is likely to have a major impact on recommendations for management/ecosystem engineering.

Milestones (Results & Products)

- **M 6.2.1 (2012 Feb):** Report describing characterisation/categorisation of expected project result types and definition of a suitable database structure for the web-based Ecosystem services RAT.
- **M 6.2.2 (2012 Feb)**: Identify opportunities for mathematical modelling or statistical analysis and develop collaborative projects as appropriate e.g. bio-control of crop pests in heterogeneous landscapes; the design and analysis of experimental studies; or on the relationship between biodiversity and ESF/ESS.
- **M 6.2.3 (2013 Feb)**: ER model and implementation of database and development of suitable tools for data upload.
- **M 6.2.4 (2013 Aug):** Report detailing preliminary project results to be included in M 6.2.3.
- **M 6.2.5 (2014 Feb)**: Review opportunities for the development of mathematical models and statistical analysis within the consortium & initiate further projects as appropriate.
- **M 6.2.6 (2014 Feb)**: Populate prototype web-based RAT with search & visualisation tools (e.g. map server) including preliminary project results.
- **M 6.2.7 (2014 Feb):** Prototype web-based RAT including preliminary project results.
- **M 6.2.8 (2014 Aug):** Stake-holder test and report collating feedback on both results and software tool.
- **M 6.2.9 (2015 Feb)**: Refine prototype RAT: search and visualisation tools.
- **M 6.2.10 (2016 Feb):** Report describing the web-based RAT including final representative project results.
- **M 6.2.11 (2016 Feb):** Web-based RAT including final representative project results available.

Work package number	**6.3**	**Dissemination (website, newsletter, publications, flyers & policy briefs, books, brochures)**				Start: 2011 March	
Partner	PENSOFT	CABI	MLU	UGOE	UFZ	UFZ (LUPO)	
Personmonths PM)	28	10	7	4	4	3	
Partner	CAU	IEBR	IRRI	PIK	UGR	UMAR	
Personmonths PM)	1	1	3	1	1	1	
Partner	MARDI	UAB / ICTA					TOTAL
Personmonths PM)	1	1					65

Objectives

- To communicate and disseminate results to the scientific community (scientific articles, conferences, project website, newsletter)
- To communicate and disseminate results to the general public (project website, brochures, flyers, articles in popular journals and newspapers)
- To disseminate major project results to other partners (inputs from all other workpackages)

Description of work

In this work package all project concepts and products will be communicated to stakeholders, the scientific community and the general public throughout the projects duration. Feedback will be used to adapt concepts and products. In total 4-6 larger meetings and numerous workshops will be organised, a project website will be opened to the public and LEGATO flyers and brochures and manuals for farmers will be produced. For scientists, we will use the more conventional means of dissemination through journals, conferences, e-conferences, workshops, handbooks on methodology of ecological engineering and books summarising the state of the art and the results of LEGATO. In addition to this, however we will use up-to-date-Internet technologies based on Web 2.0 and Semantic Web principles as a general platform for the dissemination of LEGATO's results.

The overriding emphasis will be on disseminating high quality, comprehensive information about the main topics and consequent risks to a wide variety of audiences and users of different background, educational level and motivation.

General communication and dissemination strategy will be developed in the first four months of the project to address two main challenges: (1) to go beyond conventional means of dissemination of project results to academic societies and policy makers to reach the *widest possible specialist and especially non-specialist audience* among the end users (2) to reach multicultural and multi-language societies based in two geographically remote and culturally different geographic regions, Central Europe and Southeast Asia. Reaching so different target groups will be possible by a combination of *Global Information Access* and *Local Knowledge Delivery* principles. The *Global Information Access* principle assumes widest possible use of Internet to disseminate and popularise project results to widest possible audience. In the spirit of LEGATO, the *Local Knowledge Delivery* principle will be implement to improve local (e.g., rural) livelihoods through enhanced local access to and management of scientific information on agriculture and the environment, by integrating international and indigenous information sources, linking national information networks and establishing sustainable local demand for access to information sources. The commitment of CABI SE Asia, working for several decades in partnership with Southeast Asia and East Asia economies will facilitate coordination with local institutions to ensure project implementation in a smooth and collaborative way with special emphasis on hardly-to-reach traditional societies in the region.

The LEGATO website and Internal Communication Platform (ICP) will be developed in the first four months of the project. ICP will be largely used for communication among partners and for archiving the project-related documents. The website will feature tools for information exchange and collaboration between stakeholders, comprehensive search engine to access information and outputs from the project database, information feeds for the latest news and updates and social networking tools for building online communities and to connect with end users. To raise awareness, the website can accommodate and provide feeds, links and banner ads to similar and/or partner websites, feature in popular search queries as well as advertise with major search engines like Google. LEGATO's website will serve as central collection point of not only of project's results – papers, documents, presentations and reports - but also of any

type of documents related to ecological engineering, biodiversity, sustainable land-use, mitigation practices, etc. The LEGATO Online Library will gather and make available to the general public all relevant information.
The BioRisk Open Access journal established within the FP6 IP ALARM (PENSOFT) will serve as a primary scientific journal for publication of project results. Manuals/guidelines or other kind of supporting publications on ecologically engineered landscapes in the project countries (Germany, Vietnam, Malaysia, Philippines) will be published by PENSOFT and broadly disseminated between the target groups. Popular newspaper articles, press releases and case study reports will be regularly presented to the mass media. All of these have to be published in the relevant languages of the participating countries (i.e. English, German, Vietnamese). This way, policy makers, farmers and conservationists will get acquainted with the latest projects achievements and will be able to incorporate them into administrative documents and management plans. Other publication materials including leaflets and posters will be produced and disseminated between the interested parties.

Milestones (Results & Products)

- **M 6.3.1 (2011 March):** Web conference for agreement on the General Communication Strategy and project logo
- **M 6.3.2 (2011 June):** Public workshop
- **M 6.3.3 (2011 June):** Elaboration of General Communication Strategy report
- **M 6.3.4 (2011 May):** Logo, brochures/flyers (for the general public and interested scientists)
- **M 6.3.5 (2011 June):** Website open to the public which describes project concepts, setup and progress
- **M 6.3.6 (2012 Feb)**: Discussion of planned publications (books, guidelines)
- **M 6.3.7 (2012 Feb):** Scientific workshop
- **M 6.3.8 (2012 Aug):** Publication and dissemination of results via brochures/books (e.g. multilingual manuals/guidelines for e.g. best land-use practices in the project countries; models describing the relationship between land use characteristics, biodiversity and ecosystem services; etc.)
- **M 6.3.9 (2012 Oct):** Several publications in both popular and scientific media (e.g. BioRisk journal)
- **M 6.3.10 (2014 Feb):** Publication of policy briefs for project results
- **M 6.3.11 (2014 Oct):** Publication of indicator brochure for stakeholders and managers
- **M 6.3.12 (2015 Feb):** Information flyers for ecological engineering, RAT and/or online tool applications)
- **M 6.3.13 (continuously)**: Production of a series of scientific publications in fundamental and applied journals which integrate models and experiments towards the goal of a biodiversity conservation programme on the one and a standardised approach for Environmental Impact Assessment on the other hand.

12.7 WP 7: Coordination

Overall responsibility of WP 7: UFZ (Josef Settele, Stefan Klotz, Ingolf Kühn, Ralf Seppelt, Joachim Spangenberg)

General aims of the WP: the successful administration, management and coordination of the project. This as well includes training of scientists involved in the consortium, capacity building, and training people in the AoI working as volunteers (citizen scientists). One important measure of this should be the successful completion of LEGATO and the wide dissemination and incorporation of the results to and within the scientific community, stakeholder groups, policy makers and the general public.

Work package number	**7.1**	**Scientific Coordination**				Start: 2011 March	
Partner	UFZ	CABI	CKFF				TOTAL
Personmonths PM)	22	4	3				29

Objectives

- To coordinate the project, in particular,
- to communicate and disseminate results within the consortium;
- to communicate and disseminate results to the scientific community (conferences, scientific journals), in close cooperation with WP 6;
- to regularly maintain the scientific contact to the coordination project GLUES;
- to elaborate the scientific content and relevant topics of i) progress workshops, ii) Project Coordination Committee meetings, and iii) General Assembly meetings;
- to initiate and maintain links to the Advisory Board and stakeholders at national and international level, especially involve those ministries of the participating countries responsible for science, agriculture and environment, and their subordinate agencies;
- to interact with stakeholders to define research needs and ensure applicable products (workshops);
- to communicate environmental policy relevant results to policy makers/managers and other stakeholders;
- to establish and maintain links to other relevant projects of this and related calls.

Description of work

The project success is dependent on successful communication between all participating research groups (e.g., in the selection of research sites, in the development of sampling protocols, in the joint collaboration in the field and on the scientific topics and research questions etc.). An electronic tool permitting a systematised information exchange plus open debates is to be installed to enable structured discourses, to file data to make them easily accessible, and for mutual information about the state of research. As this information has different characteristics regarding the public access to it (see the deliverables list), different access levels will be established.

Work and information flow among the WPs will be coordinated and supervised by the Project Coordinator (UFZ), research within WPs by the WP leaders (remaining WP partners). The knowledge to be generated by the project needs broad dissemination, into the scientific community to make it available, to be recognized, and to built on further academic developments (to be performed in close cooperation with WP 6).

In the first months, the advisory boards will be constituted and have one or two meetings, and the communication strategy will be developed and implemented with the tools available.

The coordination will establish links and secure scientific cooperation with other relevant EU and national projects. Contact to LEGATO partners, partner projects as well as the coordination project GLUES will be maintained by regular visits, video conferences, Skype, email exchange, phone calls etc.

Milestones (Results & Products)

- **M 7.1.1 (2011 May):** Developing a communication strategy and setting up the necessary infrastructure, including access to existing regular electronic newsletters, the electronic open communication platform.
- **M 7.1.2 (2011 Aug):** Establishment of the advisory board.
- **M 7.1.3 (continuously):** Scientific papers, conference presentation and proceedings, booklet(s), books, CD-ROMs (whatever is appropriate).
- **M 7.1.4 (every 6th month):** PCC meeting.

Work package number	**7.2**	**Management**					Start: 2011 March
Partner	UFZ						TOTAL
Personmonths PM)	17						17

Objectives

- Administrative management of the project, in particular:
- administrative and scientific project controlling and reporting;
- day-to-day operational management of the entire project;
- design of an Internet based internal communication, information, and data exchange system;
- provision of efficient means for data management (maintenance of data bank);
- dissemination of major project results to the general public (internet presentation, brochures, articles in popular media; close link to WP 6);
- organisation of progress workshops, Project Coordination Committee meetings and General Assembly meetings;
- regular maintenance of administrative contacts to the funding ministry (BMBF) and managing agency (DLR);
- organisation of regular reports to the DLR/BMBF;
- overall budgetary issues of the project.

Description of work

We will set up a system for exchange of data, results, coordination decisions, information material, and for reporting among partners primarily using email and an Intranet portal. Building on existing portals from previous projects (e.g., ALARM) we will adjust the design to the needs of LEGATO. The design will be implemented by WP6. The Intranet will allow each partner, the WP leaders, and the overall coordinator to regularly monitor progress in data collation, analysis, and Milestones by checking the latest updates in a results section. Regularly updated time schedules for work within WPs will be placed on a prominent location of the Intranet pages. The Intranet portal and Skype will also be used as an internal discussion forum for items that may emerge within WPs between the main project meetings and need live discussions for rapid decisions.

The knowledge to be generated by the project needs broad dissemination, beyond the scientific community to make it available to the general public and decision makers and to make sure it is taken into due account in the decision making process.

There will be a Kick-off meeting (1st General Assembly meeting) within the first months of the project and - approximately at 12 months intervals – further meetings for the whole consortium to facilitate coordination and integration of research and results. The established Advisory Board will be invited to all workshops. During these meetings we will review progress and control quality of results. The intricate network of interactions among members and with the Advisory Board allows a particularly thorough quality control of the work, as it will be done both within and among WP teams.

We will produce annual reports for DLR/BMBF.

Milestones (Results & Products)

- **M 7.2.1 (2012 Feb):** 1st report to the DLR/BMBF.
- **M 7.2.2 (2013 Feb):** 2nd report to the DLR/BMBF.
- **M 7.2.3 (2014 Feb):** 3rd report to the DLR/BMBF.
- **M 7.2.4 (2015 Feb):** 4th report to the DLR/BMBF.
- **M 7.2.5 (2016 Feb):** 5th report to the DLR/BMBF.
- **M 7.2.6 (2011 May):** 1st GA meeting.
- **M 7.2.7 (2012 Feb):** 2nd GA meeting.
- **M 7.2.8 (2013 Feb):** 3rd GA meeting.
- **M 7.2.9 (2014 Feb):** 4th GA meeting.
- **M 7.2.10 (2015 Feb):** 5th GA meeting.
- **M 7.2.11 (2016 Feb):** 6th GA meeting.
- **M 7.2.12 (continuously updated):** List(s) of published outputs of project; in particular scientific and non-scientific paper contributions (newspapers, scientific papers).

Work package number	**7.3**	**Training**					Start: 2011 March
Partner	IEBR	UFZ	UGOE	OLANIS	CABI	CAU	
Personmonths PM)	3	3	2	2	2	1	
Partner	IRRI	UFZ (LUPO)	MLU	UGR	UMAR		TOTAL
Personmonths PM)	4	1	1	1	1		20

Objectives

- To provide advanced training of researchers, key staff and research managers.
- To provide training for industrial executives (for SME's) and potential users.
- To organise exchange programs for PhD students at partner organisations to facilitate the exchange of know-how.
- To provide capacity building for researchers and stakeholders involved.
- To organizes training workshops for citizen scientists.
- To develop and realize an indicator course for stakeholders and environmental managers.

Description of work

Here we will only provide some examples; further activities might most probably arise in the course of LEGATO.

Statistics for Ecologists

The practical applications of statistics will be covered in a workshop exploring the use of statistical computer packages. Especially, we will focus on empirical modelling techniques which will allow spatial and temporal analyses of drivers and responses. These will include basic applications for junior participants (such as generalised linear models, simple multivariate applications) as well as more advanced methods for more experienced scientists (e.g., autoregressive methods, generalised additive models, boosted regression trees, etc.).

GIS training

GIS training seminars will be organised for PhD students and researchers. These are intended to give an overview and explore the possibilities in landscape ecology and biology using GIS technology. The basics of cartography, areas of application for GIS and its basic functions will be explored. Participants will gain experience in the theoretical problems associated with capturing, handling and analysing spatial (map) data by computer and learn about these problems through the practical use of Arc/Info and Arc/View, widely used commercially available GIS. Elements of GIS which can be used to work on and display the results of landscape ecological research activities will be investigated including links with external databases, statistical summaries and cartography, software extensions for GIS systems, environmental monitoring using GIS and Internet mapping.

Training workshops for citizen scientists

A workshop will be organized to train the involved citizen scientist with the aims of LEGATO, research questions to contribute to, collation of species observation and methods to incorporate this information to the available tools (such as Web interfaces, iPhone, iPod). These will be prepared jointly by the IT specialists, the specialists for the respective organisms local experts and will be transferred into the locally spoken languages.

Indicator framework course

To support the application of the project results, a course will be developed and carried out to disseminate major project results and applications as well as the elaborated indicator framework to the local communities and stakeholders. These will be prepared and conducted by the topical specialists in close cooperation with the local partners.

Milestones (Results & Products)

- **M 7.3.1 (2012 Feb):** Introductory course "Statistics for Ecologists".
- **M 7.3.2 (2012 Aug):** GIS and database management training course.
- **M 7.3.3 (2013 Feb):** Advanced course "Statistics for Ecologists".
- **M 7.3.4. (2013 Aug):** Training workshops for citizen scientists.
- **M 7.3.5 (2014 Feb):** Successful completion of GIS workshop, resulting in increased skills and experience.
- **M 7.3.6 (2014 Nov):** Indicator framework course.

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