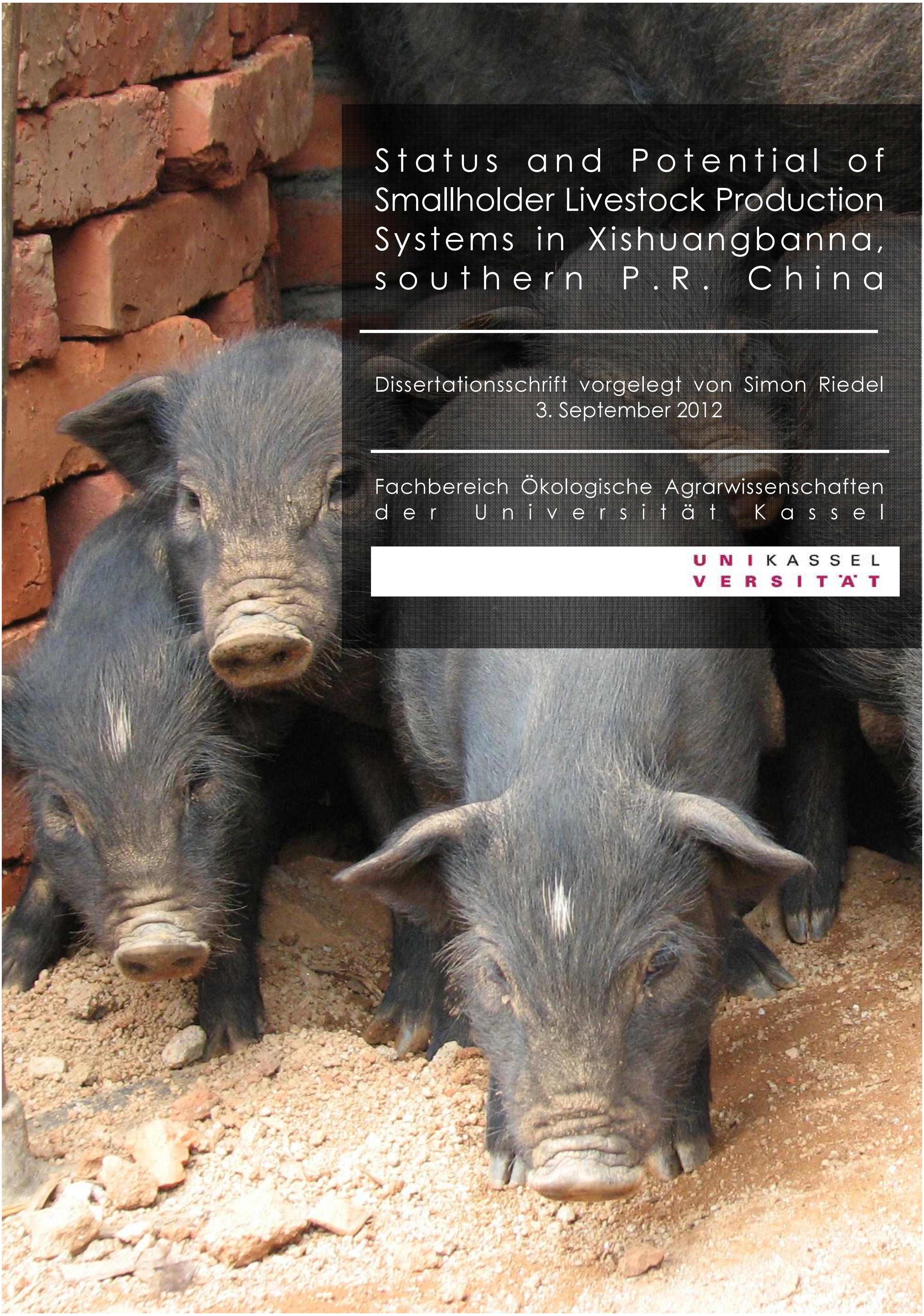

Status and Potential of Smallholder Livestock Production Systems in Xishuangbanna, southern P.R. China

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Göttingen, den 29. August 2012 Simon Riedel

To my father
† 06. September 2006

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Summary

With Chinas rapid economic development during the last decades, the national demand for livestock products has quadrupled within the last 20 years. Most of that increase in demand has been answered by subsidized industrialized production systems, while million of smallholders, which still provide the larger share of livestock products in the country, have been neglected. Fostering those systems would help China to lower its strong urban migration streams, enhance the livelihood of poorer rural population and provide environmentally save livestock products which have a good chance to satisfy customers demand for ecological food. Despite their importance, China's smallholder livestock keepers have not yet gained appropriate attention from governmental authorities and researchers. However, profound analysis of those systems is required so that adequate support can lead to a better resource utilization and productivity in the sector.

To this aim, this pilot study analyzes smallholder livestock production systems in Xishuangbanna, located in southern China. The area is bordered by Lao and Myanmar and geographically counts as tropical region. Its climate is characterized by dry and temperate winters and hot summers with monsoon rains from May to October. While the region is plain, at about 500 m asl above sea level in the south, outliers of the Himalaya mountains reach out into the north of Xishuangbanna, where the highest peak reaches 2400 m asl. Except of one larger city, Jinghong, Xishuangbanna mainly is covered by tropical rainforest, areas under agricultural cultivation and villages. The major income is generated through inner-Chinese tourism and agricultural production. Intensive rubber plantations are distinctive for the lowland plains while small-scaled traditional farms are scattered in the mountane regions.

In order to determine the current state and possible future chances of smallholder livestock production in that region, this study analyzed the current status of the smallholder livestock sector in the Naban River National Nature Reserve (NRNNR), an area which is largely representative for the whole prefecture. It covers an area of about 50 square kilometer and reaches from 470 up to 2400 m asl. About 5500 habitants of different ethnic origin are situated in 24 villages. All data have been collected between October 2007 and May 2010.

Three major objectives have been addressed in the study:

1. Classifying existing pig production systems and exploring respective pathways for development
2. Quantifying the performance of pig breeding systems to identify bottlenecks for production
3. Analyzing past and current buffalo utilization to determine the chances and opportunities of buffalo keeping in the future

In order to classify the different pig production systems, a baseline survey (n=204, stratified cluster sampling) was carried out to gain data about livestock species, numbers, management practices, cultivated plant species and field sizes as well as socio-economic characteristics. Sampling included two clusters at village level (altitude, ethnic affiliation), resulting in 13 clusters of which 13-17 farms were interviewed respectively. Categorical Principal Component Analysis (CatPCA) and a two-step clustering algorithm have been applied to identify determining farm characteristics and assort recorded households into classes of livestock production types. The variables *keep_sow_yes/no*, *TLU_pig*, *TLU_buffalo*, *size_of_corn_fields*, *altitude_class*, *size_of_tea_plantation* and *size_of_rubber_field* have been found to be major determinants for the characterization of the recorded farms.

All farms have extensive or semi-intensive livestock production, pigs and buffaloes are predominant livestock species while chicken and aquaculture are available but play subordinate roles for livelihoods. All pig raisers rely on a single local breed, which is known as Small Ear Pig (SMEP) in the region. Three major production systems have been identified: Livestock-corn based (LB; 41%), rubber based (RB; 39%) and pig based (PB; 20%) systems. RB farms earn high income from rubber and fatten 1.9 ±1.80 pigs per household (HH), often using purchased pig feed at markets. PB farms own similar sized rubber plantations and raise 4.7 ±2.77 pigs per HH, with fodder mainly being cultivated and collected in the forest. LB farms grow corn, rice and tea and keep 4.6 ±3.32 pigs per HH, also fed with collected and cultivated fodder. Only 29% of all pigs were marketed (LB: 20%; RB: 42%; PB: 25%), average annual mortality was 4.0 ±4.52 pigs per farm (LB: 4.6 ±3.68; RB: 1.9 ±2.14; PB: 7.1 ±10.82). Pig feed mainly consists of banana pseudo stem, corn and rice hives and is prepared in batches about two to three times per week. Such fodder might be sufficient in energy content but lacks appropriate content of protein. Pigs therefore suffer from malnutrition, which becomes most critical in the time before harvest season around October. Farmers reported high occurrences of gastrointestinal parasites in carcasses and often pig stables were wet and filled with manure. Deficits in nutritional and hygienic management are major limits for development and should be the first issues addressed to improve productivity. SME pork was found to be known and preferred by local customers in town and by richer lowland farmers. However, high prices and lacking availability of SME pork at local wet-markets were the reasons which limited purchase. If major management constraints are overcome, pig breeders (PB and LB farms) could increase the share of marketed pigs for town markets and provide fatteners to richer RB farmers. RB farmers are interested in fattening pigs for home consumption but do not show any motivation for commercial pig raising.

To determine the productivity of input factors in pig production, reproductive performance, feed quality and quantity as well as weight development of pigs under current management were recorded. The data collection included a progeny history survey covering 184 sows and 437 farrows, bi-weekly weighing of 114 pigs during a 16-months time-span on 21 farms (10 LB and 11 PB) as well as the daily recording of feed quality and quantity given to a defined number of pigs on the same 21 farms. Feed samples of all recorded ingredients were analyzed for their respective nutrient content. Since no literature values on the digestibility of banana pseudo stem – which is a major ingredient of traditional pig feed in NRNNR – were found, a cross-sectional digestibility trial with 2x4 pigs has been conducted on a station in the research area. With the aid of PRY Herd Life Model, all data have been utilized to determine the systems' current (Status Quo = *SQ*) output and the productivity of the input factor "feed" in terms of saleable life weight per kg DM feed intake and monetary value of output per kg DM feed intake. Two improvement scenarios were simulated, assuming 1) that farmers adopt a culling management that generates the highest output per unit input (Scenario 1; *SC I*) and 2) that through improved feeding, selected parameters of reproduction are improved by 30% (*SC II*). Daily weight gain averaged 55 ± 56 g per day between day 200 and 600. The average feed energy content of traditional feed mix was 14.92 MJ ME. Age at first farrowing averaged 14.5 ± 4.34 months, subsequent inter-farrowing interval was 11.4 ± 2.73 months. Littersize was 5.8 piglets and weaning age was 4.3 ± 0.99 months. 18% of piglets died before weaning. Simulating pig production at actual status, it has been show that monetary returns on inputs (ROI) is negative (1:0.67), but improved (1:1.2) when culling management was optimized so that highest output is gained per unit feed input. If in addition better feeding, controlled mating and better resale prices at fixed dates were simulated, ROI further increased to 1:2.45, 1:2.69, 1:2.7 and 1:3.15 for four respective grower groups. Those findings show the potential of pork production, if basic measures of improvement are applied. Future exploration of the environment, including climate, market-season and culture is required before implementing the recommended measures to ensure a sustainable development of a more effective and resource conserving pork production in the future.

The two studies have shown that the production of local SME pigs plays an important role in traditional farms in NRNNR but basic constraints are limiting their productivity. However, relatively easy approaches are sufficient for reaching a notable improvement. Also there is a demand for more SME pork on local markets and, if basic constraints have been overcome, pig farmers could turn into more commercial producers and provide pork to local markets. By that, environmentally safe meat can be offered to sensitive consumers while farmers increase their income and lower the risk of external shocks through a more diverse income generating strategy.

Buffaloes have been found to be the second important livestock species on NRNNR farms. While they have been a core resource of mixed smallholder farms in the past, the expansion of rubber tree plantations and agricultural mechanization are reasons for decreased swamp buffalo numbers today. The third study seeks to predict future utilization of buffaloes on different farm types in NRNNR by analyzing the dynamics of its buffalo population and land use changes over time and calculating labor which is required for keeping buffaloes in view of the traction power which can be utilized for field preparation.

The use of buffaloes for field work and the recent development of the regional buffalo population were analyzed through interviews with 184 farmers in 2007/2008 and discussions with 62 buffalo keepers in 2009. While pig based farms (PB; n=37) have abandoned buffalo keeping, 11% of the rubber based farms (RB; n=71) and 100% of the livestock-corn based farms (LB; n=76) kept buffaloes in 2008. Herd size was 2.5 ±1.80 (n=84) buffaloes in early 2008 and 2.2 ±1.69 (n=62) in 2009. Field work on own land was the main reason for keeping buffaloes (87.3%), but lending work buffaloes to neighbors (79.0%) was also important. Other purposes were transport of goods (16.1%), buffalo trade (11.3%) and meat consumption (6.4%). Buffalo care required 6.2 ±3.00 working hours daily, while annual working time of a buffalo was 294 ±216.6 hours. The area ploughed with buffaloes remained constant during the past 10 years despite an expansion of land cropped per farm.

Further rapid replacement of buffaloes by tractors is expected in the near future. While the work economy is drastically improved by the use of tractors, buffaloes still can provide cheap work force and serve as buffer for economic shocks on poorer farms. Especially poor farms, which lack alternative assets that could quickly be liquidized in times of urgent need for cash, should not abandon buffalo keeping.

Livestock has been found to be a major part of small mixed farms in NRNNR. The general productivity was low in both analyzed species, buffaloes and pigs. Productivity of pigs can be improved through basic adjustments in feeding, reproductive and hygienic management, and with external support pig production could further be commercialized to provide pork and weaners to local markets and fattening farms. Buffalo production is relatively time intensive, and only will be of importance in the future to very poor farms and such farms that cultivate very small terraces on steep slopes. These should be encouraged to further keep buffaloes. With such measures, livestock production in NRNNR has good chances to stay competitive in the future.

Zusammenfassung

Durch die rasante wirtschaftliche Entwicklung Chinas in den vergangenen zwei Jahrzehnten hat sich die nationale Nachfrage nach tierischen Erzeugnissen in den letzten 20 Jahren vervierfacht. Diese erhöhte Nachfrage wurde primär durch die starke Expansion der subventionierten industriellen Tierproduktion gedeckt, während viele Millionen von Kleinbauern, welche bis heute den größten Anteil der tierischen Erzeugnisse des Landes produzieren, wirtschaftlich unberücksichtigt blieben. Wie in der vorliegenden Arbeit gezeigt werden kann, scheint die Förderung gerade dieser Systeme sich in verschiedener Hinsicht positiv auf Chinas Gesamtsituation auszuwirken. So verlangsamt die wirtschaftliche Stärkung der ruralen Gebiete den gegenwärtig starken Trend der Urbanisierung, der in ganz China zu einem soziokulturellen Ungleichgewicht führt und verschiedene politische aber auch wirtschaftliche Probleme nach sich zieht. Eine umweltverträglichere Tierproduktion, welche den stark wachsenden Markt für ökologische Erzeugnisse bedienen könnte, würde gleichzeitig die ökonomische Situation der oft verarmten ländlichen Bevölkerung verbessern. Trotz dieser großen Bedeutung haben Chinas kleinbäuerliche Tierhalter nur wenig Aufmerksamkeit von Behörden und Forschern erhalten. Um eine angemessene Unterstützung einer besseren Ressourcennutzung und Produktivität dieses Sektors zu gewährleisten, ist eine intensive Analyse solcher Systeme ist erforderlich.

Zu diesem Zweck untersucht die vorliegende Pilotstudie Strukturen der kleinbäuerlichen Nutztierhaltung in Xishuangbanna, im Süden der Provinz Yunnan. Xishuangbanna wird südlich von Laos und westlich von Myanmar begrenzt und ist geographisch den Tropen zuzurechnen. Das Klima ist durch trockene und milde Winter sowie heiße Sommer mit Monsunregen von Mai bis Oktober gekennzeichnet. Während die Region im Süden etwa 500 m über Normal Null (mNN) gelegen ist, werden im Norden durch Ausläufer des Himalayagebirges Höhen von über 2400 mNN erreicht. Jinghong, die Hauptstadt der Region, fungiert als wirtschaftlicher und kultureller Knotenpunkt der sonst ländlichen Präfektur deren weite Gebiete vor allem tropischen Regenwald, Agrarflächen und Dörfer ausmachen. Die Haupteinnahmequellen der Bevölkerung sind inner-chinesischer Tourismus sowie landwirtschaftliche Produktion. Weitläufige Gummiplantagen sind charakteristisch für die Tiefebenen, während kleinstrukturelle traditionelle Bauernhöfe in den höheren Lagen verbreitet sind.

Um mögliche zukünftige Chancen der kleinbäuerlichen Nutztierhaltung in der Region zu erarbeiten, analysiert diese Studie den aktuellen Status der kleinbäuerlichen Tierhaltung in dem *Naban River National Nature Reserve (NRNNR)*, ein Gebiet, das weitgehend repräsentativ für die gesamte Präfektur ist. Es umfasst eine Fläche von etwa 50 Quadratkilometer und reicht von 470 bis 2400 m ü. d. M. Rund 5500 Einwohner unterschiedlicher ethnischer Herkunft leben hier in ca. 20 Dörfern. Alle Feldstudien dieser Arbeit wurden zwischen Oktober 2007 und Mai 2010 durchgeführt.

Die Studie umfasst drei hauptsächliche Abschnitte, welche von eine generellen Einführung und einer abschließende Diskussion eingefasst sind:

1) Die Klassifizierung der kleinbäuerlichen Schweinebetriebe und die Erarbeitung möglicher Pfade für deren zukünftige Entwicklung.
2) Die Quantifizierung der Produktivität von Inputfaktoren sowie der reproduktiven Leistung von Schweinebetrieben zur Identifizierung von Schwachstellen in den Systemen.
3) Die Analyse der aktuellen Nutzung von Büffeln zur Erarbeitung möglicher Entwicklungspfade für die Zukunft.

Zur Klassifizierung der kleinbäuerlichen Schweinebetriebe wurde eine *Baseline*-Datenerhebung durchgeführt (n=204, stratifiziertes Cluster-Sampling) um die vorhandenen Nutztierarten, Tierzahlen, gängige Praktiken der Tierhaltung, angebaute Kulturpflanzen sowie die jeweilige Größe der landwirtschaftlichen Nutzfläche von Haushalten und ihre sozioökonomischen Merkmale aufzunehmen. Die Strata wurden auf Dorfebene aus den Kriterien „ethnische Zugehörigkeit" sowie „Höhe über dem Meeresspiegel" gebildet. Aus den 13 gebildeten Clustern wurden jeweils 13-17 Betriebe zufällig ausgewählt und befragt. Eine „Categorical Principal Component Analysis" (CATPCA) sowie ein Zwei-Schritt-Clustering-Algorithmus wurden genutzt, um klassenbildende Eigenschaften der Haushalte zu identifizieren und um sie den gebildeten Klassen zuordnen zu können. Die Variablen „*HH hält Schweine ja/nein*", „*TLU*[1] *der Schweine*", *„TLU der Büffel", „Größe der Mais-Felder", „Höhen-Klasse"* sowie *„Größe der Teefelder"* und *„Größe der Gummibaum-Plantagen"* wurden als Cluster-bestimmend identifiziert und zur Klassifizierung verwendet. Alle analysierten Betriebe verfügen über extensive oder semi-intensive Tierproduktion, wobei Schweine und Büffel die beiden wichtigsten Tierarten darstellen, während Geflügel und Fischkulturen vorhanden sind, aber eine untergeordnete Rolle für den Lebensunterhalt spielen. Die einzige im Gebiet genutzte Schweinerasse wurde von den Tierhaltern mit dem Namen *„Small Ear*

[1] TLU: Tropical livestock unit; equivalent of an animal of 250 kg live weight (buffalo = 1.2 TLU; pig/sow = 0.2 TLU)

Pig“ (SMEP) benannt, eine Rasse, welche außerhalb von Xishuangbanna unbekannt ist. Die drei hauptsächlichen Wirtschaftssysteme, welche in dem Gebiet unterschieden wurden, sind: Nutztierhaltung-und-Mais-basierte (LB; 41%), Kautschuk-basierte (RB; 39%) und Schwein-basierte (PB; 20%) Systeme. RB Betriebe generieren ein hohes Einkommen aus dem Anbau von Kautschuk und mästen 1,9 ± 1,80 Schweine pro Haushalt (HH), welche meist mit zugekauften Futtermitteln gemästet werden. PB Farmen besitzen ähnlich große Kautschuk-Plantagen und züchten Schweine. Im Schnitt waren 4,7 ± 2,77 Schweine pro HH vorhanden. Das Futter wird hauptsächlich auf eigenen Feldern kultiviert oder im Wald gesammelt. LB Betriebe bauen Mais, Reis und Tee an, und sind ebenfalls Schweinezüchter. Pro HH wurden 4,6 ± 3,32 Schweine gezählt. Auch LB Bauernhöfe beziehen die Futtermittel von eigenen Kulturflächen und aus dem Wald. Im Schnitt werden 29% der Schweine pro HH vermarktet (LB: 20%; RB: 42%; PB: 25%), die durchschnittliche jährliche Sterblichkeit liegt bei 4,0 ± 4,52 Schweinen pro Betrieb (LB: 4,6 ± 3,68; RB: 1,9 ± 2,14; PB: 7,1 ± 10,82). Das im Gebiet genutzte Schweinefutter besteht hauptsächlich aus dem Pseudostamm der Banane, gemahlenem Mais und Reishülsen. Pro Woche werden zwei- bis dreimal größere Mengen der Futtermischung hergestellt und zweimal täglich an die Schweine verfüttert. Das Futter hat einen ausreichenden Gehalt an Energie, weist aber einen defizitären Proteingehalt auf. Die Schweine leiden daher an Mangelernährung, welche insbesondere in der Vorerntezeit zu Mangelerscheinungen und Fortpflanzungsstörungen führt. Bauern erkennen regelmäßig hohe Vorkommen von Magen-Darm-Parasiten in Schlachtkörpern, die Tierbehausungen sind auffallend schmutzig und durchgehend feucht bis nass. Die beobachteten Defizite im Ernährungs- und Gesundheitsmanagement sind maßgeblich für die schlechte Leistung der Schweinehaltung verantwortlich und sollten bei der Erarbeitung von Maßnahmen zur Produktivitätssteigerung eine hohe Priorität einnehmen. Das Fleisch der SMEP ist lokal bekannt und wurde von Konsumenten in der Stadt Jinghong und wohlhabenderen Bauern gegenüber herkömmlichem Schweinefleisch bevorzugt. Hohe Preise und mangelnde Verfügbarkeit des Fleischs auf traditionellen Märkten sind die hauptsächlichen Gründe für einen eingeschränkten Konsum des SMEP-Fleischs. Die positive Marktsituation birgt folglich die Chance in sich, dass Schweinezüchter (PB und LB Bauernhöfe) einen höheren Absatz generieren können, sofern die erwähnten Defizite im Management verbessert sind. Zusätzlich bietet die Nachfrage von wohlhabenden RB Bauern nach Absetzferkeln eine weitere Marktchance. RB HH selbst jedoch haben kein kommerzielles Interesse an der Tierhaltung. Vielmehr kann vermutet werden, dass die Schweinehaltung auf RB Bauernhöfen durch die fast ausschließliche Nutzung von zugekauftem Futter nicht kostendeckend ist und auf soziale und kulturelle Interessen zurückzuführen ist.

Zur Bestimmung der Produktivität von Inputfaktoren sowie der Quantifizierung reproduktiver Leistungsparameter, der Futterqualität und -quantität und der Gewichtsentwicklung von Schweinen unter aktuellem Management wurden folgende Daten erhoben: Eine *Progeny-History* Umfrage, mittels welcher die reproduktive Vergangenheit von 184 Sauen und 437 Würfen erhoben wurden; das regelmäßige Wiegen von 114 Schweinen auf 21 (10 LB und 11 PB) Bauernhöfen im Abstand von 2 Wochen über einen Zeitraum von 16 Monaten; die tägliche Erfassung von Qualität und Quantität des Schweinefutters, welches in denselben 21 Haushalten jeweils an eine definierte Anzahl von Schweinen verfüttert wurde und die Analyse aller von den Bauern verwendeten Futtermitteln auf ihre Nährstoffgehalte. Da für die Verdaulichkeit des Pseudostamms der Banane – welcher wesentlicher Bestandteil der traditionellen Futterrationen der analysierten Bauernhöfen ist - keine Literaturwerte gefunden werden konnten, wurde in einem Versuch mit n=2x4 Schweinen (cross-sectional design) die Verdaulichkeit des Futtermittels untersucht.

Mit Hilfe des bioökonomischen *PRY Herd Life* Modells wurde die durchschnittliche Produktivität – als Ertrag (Geldwert oder Lebendgewicht) pro Inputfaktor (kg Trockenmasse Futtermittel) – der Systeme unter aktuellem Management (Status Quo = SQ) quantifiziert. Mittels Szenarien wurden zwei Stufen einer verbesserten Haltung simuliert: Scenario I (SC I) nimmt an, dass der Schlachtzeitpunkt der Schweine (Sauen und Masttiere), *ceteris paribus*, auf die höchste Produktivität (Lebendgewicht pro kg Trockenmasse Futter) optimiert wird, während Scenario II (SC II) annimmt, dass verbessertes Hygiene-Management sowie energiereicheres Futter zu einer 30%igen Verbesserung von Erstwurfalter, Zwischenwurfzeit und der Sterblichkeit vor dem Absetzen führt.

Die durchschnittliche tägliche Gewichtszunahme der Gesamtpopulation im Alter zwischen Tag 200 und 600 lag bei 55 ± 56 g. Insgesamt wies die traditionelle Futtermischung einen Energiegehalt von 14,92 MJ ME pro kg Trockenmasse auf. Das Erstwurfalter der Sauen betrug 14,5 ± 4,34 Monate, während die Zwischenwurfzeit 11,4 ± 2,73 Monate betrug. Die Wurfgröße betrug im Schnitt 5,8 Ferkel und das Absetzalter betrug 4,3 ± 0,99 Monate. Im Schnitt starben 18% aller lebendgeborenen Ferkel vor dem Absetzen. Die Simulation der Produktivität unter SQ zeigt, dass die durchschnittliche Schweinehaltung im Gebiet einen negativen Ertrag generiert (1:0,67), welcher sich durch die Veränderungen im SC I auf einen positiven Wert verbessert (1:1.2). Durch die zusätzlich simulierte Verbesserung der oben genannten Parameter (SC II) kann der Ertrag auf 1:2,45; 1:2,69; 1:2,7 und 1:3,15 für Schweine aus vier verschiedenen Wachstums-Kategorien gesteigert werden. Die Ergebnisse zeigen das Potenzial der Schweinehaltung im NRNNR, welches durch die Einführung grundlegender Maßnahmen zur Verbesserung der Haltungsbedingungen erreicht werden kann. Eine weitere Analyse des Produktionsumfelds, welche die klimatischen Bedingungen, die Saisonalität von Feldfrüchten, sowie eine detailliertere Marktanalyse umfasst, sollte durchgeführt werden, um eine nachhaltige Entwicklung zur effektiven und ressourcenschonenden Produktion von Schweinefleisch in der Zukunft gewährleisten zu können.

Durch die beiden Studien über die Schweinehaltung im NRNNR konnte gezeigt werden, dass die Haltung von SMEP eine zentrale Rolle innerhalb der kleinbäuerlichen Strukturen einnimmt, deren Produktivität aber durch grundlegende Defizite stark eingeschränkt ist. Es konnten jedoch Ansätze identifiziert werden, welche zu einer merklichen Verbesserung der Produktivität führen. Die Nachfrage nach SMEP-Fleisch auf lokalen Märkten zeigt, dass die Schweinehalter nach der Durchführung der Maßnahmen einen lukrativen Markt bedienen können. Dadurch würde ein nachhaltiges Tierprodukt im Markt verfügbar sein, während die Tierhalter selbst durch die zusätzlichen Einnahmen ihr Haushalts-Risiko weiter reduzieren und so resistenter gegen unvorhergesehene negative Einflüsse werden.

Neben der Schweinehaltung nimmt die Büffelhaltung die zweitwichtigste Rolle in der Tierhaltung der Bauernhöfe ein. Während in der Vergangenheit Büffel ein Kernstück der gemischten kleinbäuerlichen Betriebe waren, sind durch das Wegfallen von Weideplätzen sowie durch die Expansion landwirtschaftlicher Nutzflächen und die stark fortschreitende Mechanisierung der Landwirtschaft die Populationen von Büffeln im NRNNR teilweise stark dezimiert worden. Die dritte Studie beabsichtigt die Rolle von Büffeln auf verschiedenen Betriebstypen in NRNNR zu beschreiben, indem Dynamiken der Büffel Populationen in Relation mit den Landnutzungs-änderungen innerhalb der letzten zehn Jahre gesetzt werden und parallel dazu der Arbeits-Aufwand und Arbeits-Ertrag eines Büffels für Haushalte quantifiziert wird.

Die Verwendung von Büffeln für die Feldarbeit und die jüngste Entwicklung der regionalen Büffel-population wurden durch Interviews mit 184 Landwirten in 2007/2008 und Gespräche mit 62 Büffel-Haltern im Jahr 2009 analysiert. Während Schweine-basierte Farmen (PB; n = 37) die Haltung von Büffel aufgegeben haben, wurden noch bei 11% der Kautschuk-basierten Farmen (RB; n = 71) und bei allen Nutztierhaltung-und-Mais-basierten Farmen (LB; n = 76) Büffel auf den Höfen vorgefunden. Die Herdengröße betrug 2,5 ± 1,80 (n = 84) Büffel im Frühjahr 2008 und 2,2 ± 1,69 (n = 62) im Jahr 2009. „*Feldarbeiten auf eigenem Land*“ wurde als Hauptgrund für Haltung von Büffeln genannt (87,3%), gefolgt von der „*Verleihung von Büffeln für Feldarbeit an*

Nachbarn" (79,0%). Als weitere Gründe galten der *„Transport von Waren"* (16,1%), das *„kommerzielle Handeln mit Büffeln"* (11,3%) und die *„Fleischgewinnung"* (6,4%). Pro Haushalt wurden täglich 6,2 ± 3,00 Arbeitsstunden für die Beaufsichtigung von Büffeln aufgewendet, während die jährliche Arbeitszeit eines Büffels zur Bearbeitung von Feldern 294 ± 216,6 Stunden war. Die Größe der Nutzflächen, welche pro Haushalt im Durchschnitt mit Büffeln bearbeitet wurde, blieb innerhalb der letzten zehn Jahre konstant, obwohl die kultivierte Gesamtfläche pro Haushalt in allen Haushalten zugenommen hat. Der hohe Arbeitsaufwand trägt zum großen Teil dazu bei, das auch in Zukunft weitere Haushalte die Haltung von Büffeln aufgeben werden, meist, um diese durch Traktoren zu ersetzen. Während der Arbeitsaufwand drastisch durch den Einsatz von Traktoren verringert wird, ist die Bodenbearbeitung mit Büffeln kostengünstiger. Weiterhin dienen die Tiere als Geldanlage, welche – im Gegensatz zu Traktoren– keinem Werteverlust unterliegen und zu jeder Zeit in Bargeld eingetauscht werden können. Diese Eigenschaft macht Büffel zu einem lebenswichtigen Vermögenswert bei unerwarteten Schocks. Insbesondere armen Betrieben, welche über keinerlei vergleichbaren Geldanlagen verfügen, ist trotz des hohen Arbeitsaufwands die weitere Nutzung von Büffeln zu empfehlen.

Die Tierhaltung spielt für den Lebensunterhalt der analysierten Haushalte eine wichtige Rolle, obwohl die Produktivität sowohl der Schweine- als auch der Büffelhaltung als niedrig einzuschätzen ist. Für die Schweinehaltung konnten die hauptsächlichen Einschränkungen für ein weiteres Wachstum in der Fütterung, dem Management der Fortpflanzung und dem Hygienemanagement identifiziert werden. Mit Hilfe von externer Unterstützung könnte die Schweinehaltung stark expandieren, um den Markt für ökologisches Fleisch in der Stadt sowie den Bedarf an Absetzferkeln wohlhabenderer RB Bauern zu bedienen. Die Büffelproduktion wurde als relativ zeitaufwändig charakterisiert. Es wird erwartet, dass nur solche Bauern, welche Reisterrassen auf sehr steilen Hängen bewirtschaften, auch in Zukunft noch auf die Unterstützung von Büffeln zurückgreifen, da solche Steilhänge nicht mit Traktoren bewirtschaftet werden können, obwohl sich die Büffelhaltung für jegliche Art von ärmeren landwirtschaftlichen Betrieben empfiehlt. Bei weiter rückgängigen Büffelzahlen sollten Anreize für solche Betriebe in Erwägung gezogen werden. Es wird erwartet, dass die Tierhaltung im NRNNR mit den vorgestellten Maßnahmen effektiver und nachhaltiger gestaltet werden kann.

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General Introduction

China's Livestock Production

Livestock production has been a core part of China's culture since ancient times. The first recordings of pigs as livestock date back to about 8.000 years B.C. (Schneider, 2011), and integrated smallholder systems with rice, buffaloes and pigs have been the original farming type in eastern Asia for centuries. That general crop-livestock production pattern has undergone drastic changes within the last thirty years and developed into very new and different production systems. Today, China's population, which represents 19.2% of the global human population (NBSC, 2012), consumes more than half of all pork worldwide, over 95% of it is produced within the country (FAO, 2012). In total, the national meat production increased fourfold within the last twenty years. Meat prices have increased four- to six-fold, and the price structure for meat itself changed: the formerly most expensive meat, chicken, today is the cheapest (Binsheng, 2002).
Those developments have only been possible through significant changes in the farming structure, especially a massive intensification and the concentration of production in core areas gathered around population hotspots in eastern China, which have served as engines of the countries recent economic metamorphosis. As an example, pig production is mainly clustered around economic centers in China's coastal eastern centers for trade and industrialized production (Figure 1).

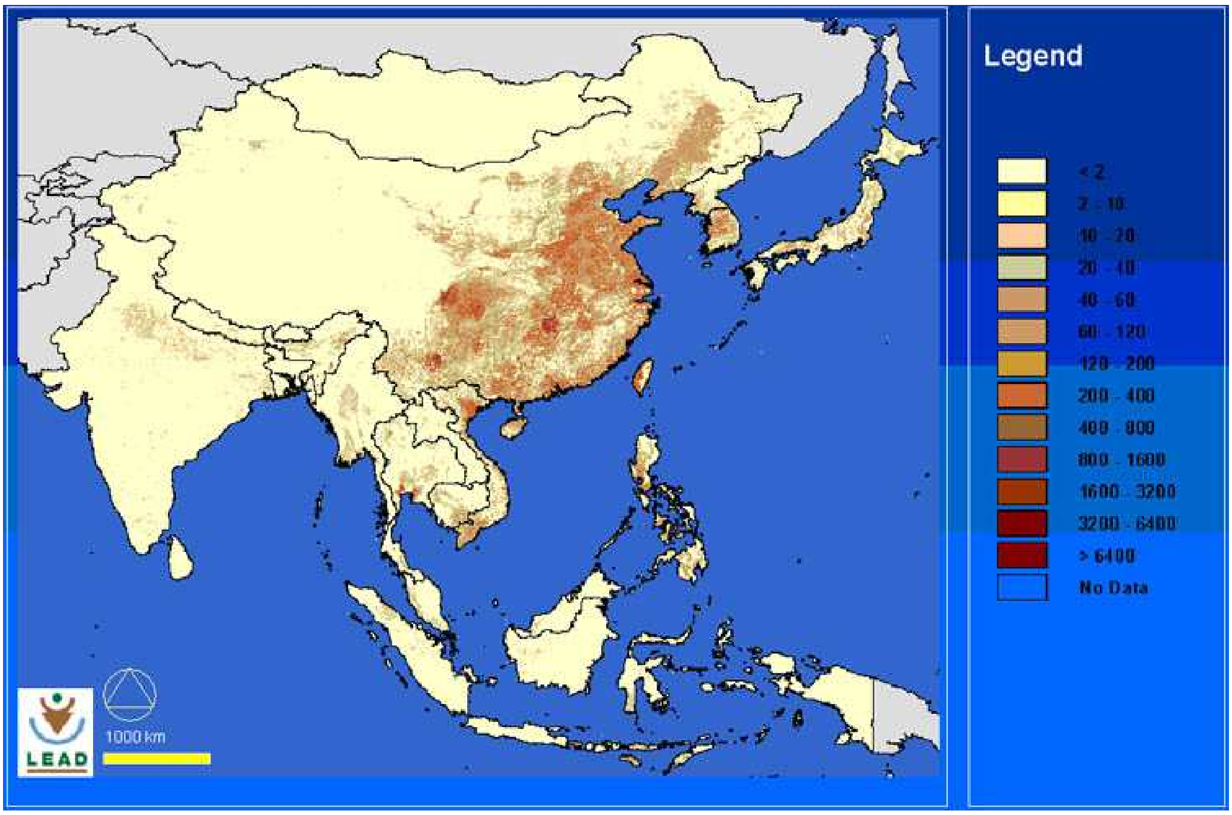

Figure 1: Pig density (head per sqkm) in China (LEAD, FAO 2002)

Intensive Production

After implementing the "Open Door Policy" in the late 1970s, which allowed international investment and first spread of private entrepreneurship in China, large industrial centers arose, which led to an accumulation of hundred thousands of workers in the country's coastal areas. Still partly in control, and recognizing the huge economic potential of those industrial areas, Chinese leaders organized the required food supply through heavy financial incentives for large-scaled agricultural production units with the aim to provide factory workers with all food required, for the cheapest price possible. Along with the increasing demand, technology and access to foreign knowledge aided to lift meat production to the newly required level. China's modern industrial meat production was founded during that time and still bears its characteristics at present.

Today meat production in China, especially pork production, is a highly subsidized, technically well equipped, powerful and continually growing sector, which receives billions of dollars as direct foreign investment, mostly from Germany and the US. Similarly to other fast growing economic branches in China, the livestock sector is facing serious challenges which require a significant restructuring in the near future. Heavy environmental pollution as well as unsafe food are the two core problems the sector has to deal with. Having literally no policies for waste disposal, it has been reported from several large-scale production areas that manure is just washed out from stables onto nearby fields, and liquids (wastewater, sewage) are led into canals leading to serious, sometimes toxic pollution of groundwater sources (Bingsheng, 2002; Gu et al., 2008; Zeng et al., 2010). The recent most famous example of unsafe livestock products in China has been the "Melamine Scandal", which affected 290,000 children and left six dead (Sharma and Paradaker, 2010). Furthermore, endemic H9N2 influenza infections were reported for the southern Chinese pig population in 2000 (Peiris et al., 2001). Scandals like these and an increasing awareness of the Chinese upper and middle class of food safety issues trigger consumers' interest in the origin and quality of their food (Gale and Kuo, 2007). In view of a further (conservatively) estimated 4% annual growth of meat demand in China, which is expected to reach its peak only after 2030 (Bingsheng, 2002), the necessity to face those challenges becomes obvious.

Although most political stakeholders still push increased productivity at all costs, a smaller minority within the Chinese government starts recognizing the environmental challenges and intervenes through the implementation of governmentally controlled actions and by permitting international organizations to collaborate in facing the threats.

Besides the recommendation to lower the negative effects of intensified meat production through technological interventions and better management, the exploration and enhancement of extensive systems in marginal areas is a key factor to sustainably cover future demands for livestock products (FAO, 2006).

Smallholder Livestock Farming

Smallholders, mostly running mixed crop-livestock farms, which are the original source for livestock products in China and southern Asia, have largely been neglected in the recent economic rush, although they still are a substantial pillar of China's livestock production in various respects: 95% of all Chinese farms farm less than two hectares of arable land (IFAD, 2009) and about 30-60% of all pigs produced in China arise from farms with an annual output of less than five fattened pigs (Binghseng, 2002). In their current state such farms might not always be able to economically compete with the above mentioned subsidized intensive livestock industry, but they contribute large amounts to the income of rural dwellers, mostly leaving behind smaller ecological footprints than large scaled systems, and, through the use of indigenous livestock breeds and local feed resources, contribute to the conservation of biodiversity and environmental protection (Box 1). Key publications dealing with the future of livestock production in East Asia emphasize the substantial role that smallholders are playing for social welfare, environmental sustainability and for meeting present and future demands for meat in China and SE Asia (Devendra and Thomas, 2002; Sere and Steinfeld, 2002). Without detailed analysis, however, extrapolations should not be plain copies of recommendations and interventions from SE Asian countries, but rather require individual analysis and sound understanding of those systems.

Box 1: Characteristics of smallholder farming

Positive effects of smallholder livestock farms

- Alleviate rural absolute poverty
- Better utilize scarce natural resources
- Conservation of biodiversity
- Decrease urban migration
- Meet future market demands
- Satisfy the growing market for green food
- Lower carbon footprint

Adopted from Devendra and Thomas, 2002

Since most of the above statements referred to poorer SE Asian countries, such as Lao, Vietnam and Thailand where the agricultural sector still contributes a great share to the nations overall GDPs, one might doubt if they are of any importance for China in its actual state. They are, if some restrictions are considered. In 1960, just fifty years ago, China has been one of the poorest countries in the world. By that time, the GDP per worker was only 2 percent of the GDP per worker in the US. The subsequent economic rise has mainly fostered urban areas of North and Northeast China, while rural areas, especially southwestern provinces, saw smaller improvements, leading to huge income disparities among rural and urban regions. The GDP of the richest and poorest Chinese provinces in 2010 were 13,058 US$ (Tianjin Province) and 2,541 US$ (Guizhou Province), a ratio of 5.1 : 1. Yunnan Province, where the present study took place, ranks second last with a GDP of 2,935 US$, similar to the GDP in Sri Lanka (2,877 US$), and higher than the GDP in neighboring Lao and Vietnam (984 and 1,174 US$), but lower that the GDP in Thailand (5,394 US$; figures from *China Statistical Database*[2] and *International Monetary Fund Data and Statistic Division*[3]). Those figures suggest that a comparison of Yunnan with its southern neighboring countries has its validity. Some institutions, such as the Asian Development Bank are even addressing Yunnan and South East Asia as GMS, the *Greater Mekong Subregion* (e.g. ADB, 2012).

It is reported from SE Asian countries that although rural economic development through support of small farms has lifted many people out of poverty in the past Asian Green Revolution (Rosegrant and Hazell, 2000), smallholder production is a very complex topic which requires careful analysis and guidance in order to ensure a development which contributes to human welfare as well as nature conservation with long-term perspectives. One of the major, often discussed arguments, is to what extent livestock production by poor households is threatening food security of very poor people through human-livestock competition for agricultural land. Some see an overall negative effect (Pimentel, 1997), while pro-livestock voices state that livestock – especially in mixed systems – often utilize leftovers from crop production and other organic wastes (Devendra and Sevilla, 2002) - leading to the use of resources which have no opportunity costs and therefore increases overall welfare. Another often used pro-livestock argument is that livestock serves as economic buffer and “savings bank” which is an irreplaceable good, while other authors see this specific role of livestock slowly disappearing due to a steadily improved rural access to banks and other money-saving options, and rather recommend farmers to spread risk by accessing non-agricultural sectors (Wiggins et al., 2010).

The example of these two views already reveals the complex role which livestock play for poorer livelihoods. SE Asia consists of very diverse sub-types of smallholder livestock producers who all operate in very different natural and social environments, meeting different constraints and challenges. Obviously, such different production systems require individual analysis so that their

[2] http://stats.gov.cn
[3] http://www.imf.org/external/data.html

respective production potential together with additional livelihood and environmental aspects can be fully realized. Concerning general recommendations made by numerous studies for smallholder livestock keepers in SE Asia, the accessibility of advanced technology, breeding schemes, the improvement of feed conversion (through quality improvement of existing feed sources and the exploration of new sources, such as high-quality feed residues), and a significant improvement of hygienic management have to be introduced at institutional as well as at farmer level (Devendra, 2002; Thomas et al., 2002; Devendra, 2007; IFPRI, 2005).

Research Objectives

Against this background, this PhD thesis analyzes the current state and future potential of smallholder livestock production in the Naban River National Nature Reserve, located in Xishuangbanna, Yunnan Province in P.R. China, through individual analysis and careful comparison of results with findings and recommendations from similar systems where appropriate. The study addresses the following research objectives:

- **Description and classification of smallholder livestock production systems**
- **Determination of production and input-factor performance of pig raising systems**
- **Analysis of current and future utilization of buffaloes**

The study aimed at identifying sustainable development pathways for these systems to ensure environmentally save livestock production and better utilization of available feed and animal genetic resources in order to contribute to improved livelihoods of farmers and their families. To this end, all livestock species farmed in the study region were considered, and data collection addressed feedstuffs and feeding, reproduction management, health care, and marketing (Figure 2). After an initial survey, pigs were identified as the economically most important species, which lead to a focus on their production. However, swamp buffaloes were a central part of mixed crop-livestock systems in the past; therefore their importance at present and in the future was also evaluated. Chicken, fish and duck were further livestock present at farms, but these have not been analyzed in detail during this study. All field data has been collected between October 2007 and May 2010.

Data Collection

Preliminary Survey

1) A first characterization of farms, the qualitative determination of available livestock species and visual classification of production systems was done through a preliminary survey. Village heads in three different villages were visited, animals were sighted and unstructured qualitative interviews were conducted in November/December 2007. Major findings were that pig production is the most important livestock keeping activity, followed by buffalo keeping. Often chicken are kept as well in fully extensive free scavenging systems. The general mode of pig production is semi-intensive, mostly penned; local breeds are fed with locally available feed sources.

Baseline Survey

2) Based on the above findings, a systematic survey (structured interviews with 208 heads of farm households) was designed, which aimed at quantifying livestock species, breeds, and input and output factors; in addition the households' economic and social characteristics were to be determined. Information on plant production was recorded as well, accounting for the strong integration of livestock and crop production. Results of this survey were used to classify farms and determine the general role of pig production for the different types of farms.

Determination of current buffalo production and assessment of its future role

3) Based on the finding that many farmers abandoned buffalo keeping within the last years, this species' present importance for farms and its future utilization were explored through a further survey (structured interviews with 62 buffalo keepers) which mainly addressed issues of buffalo work economics and degree of integration of buffalo into the general farm setup.

Feeding management and growth performance of pigs

4) The practices of pig feeding and related pig growth were analyzed through a sixteen months longitudinal study which included constant recording of feedstuffs used, quantification of the amounts of feeds offered to pigs and the weight changes of 114 pigs on 21 farms.

Reproductive performance of pigs

5) In order to assess the current reproductive performance of pigs on 162 representative farms, relevant parameters were gathered through a progeny history questionnaire addressing 184 sows and 437 litters.

Digestibility of cooked and raw banana pseudo stem in pigs

6) The pseudostem of a wild banana species (*Musa acuminata Lacatan*) occurring in the forest was found to be a major feed for pigs in all farm types. The digestibility of the proximate constituents of this feedstuff in pigs was therefore tested in an on-station digestibility trial.

Testing improved feed rations for pigs

7) Soybean is a locally available protein source. Its inclusion in the traditional pig diet and effects on pig growth have been tested in a controlled on-farm experiment with two groups of growing pigs (n=8 each) fed with the traditional (see point 6) and a protein-improved diet, respectively, for 90 days.

The data of these interviews and trials have been merged in this thesis; its main chapters focus on the farm classification and general system description (points 1 and 2, integrated into chapter 2), reproductive and input factor performance of pigs (points 4, 5, 6, integrated into chapter 3) and the assessment of current and future buffalo utilization in the research area (point 3, integrated into chapter 4). Based on the findings of the previous chapters, the chances and challenges of livestock keepers in the research area are discussed and recommendations are drawn (chapter 5).

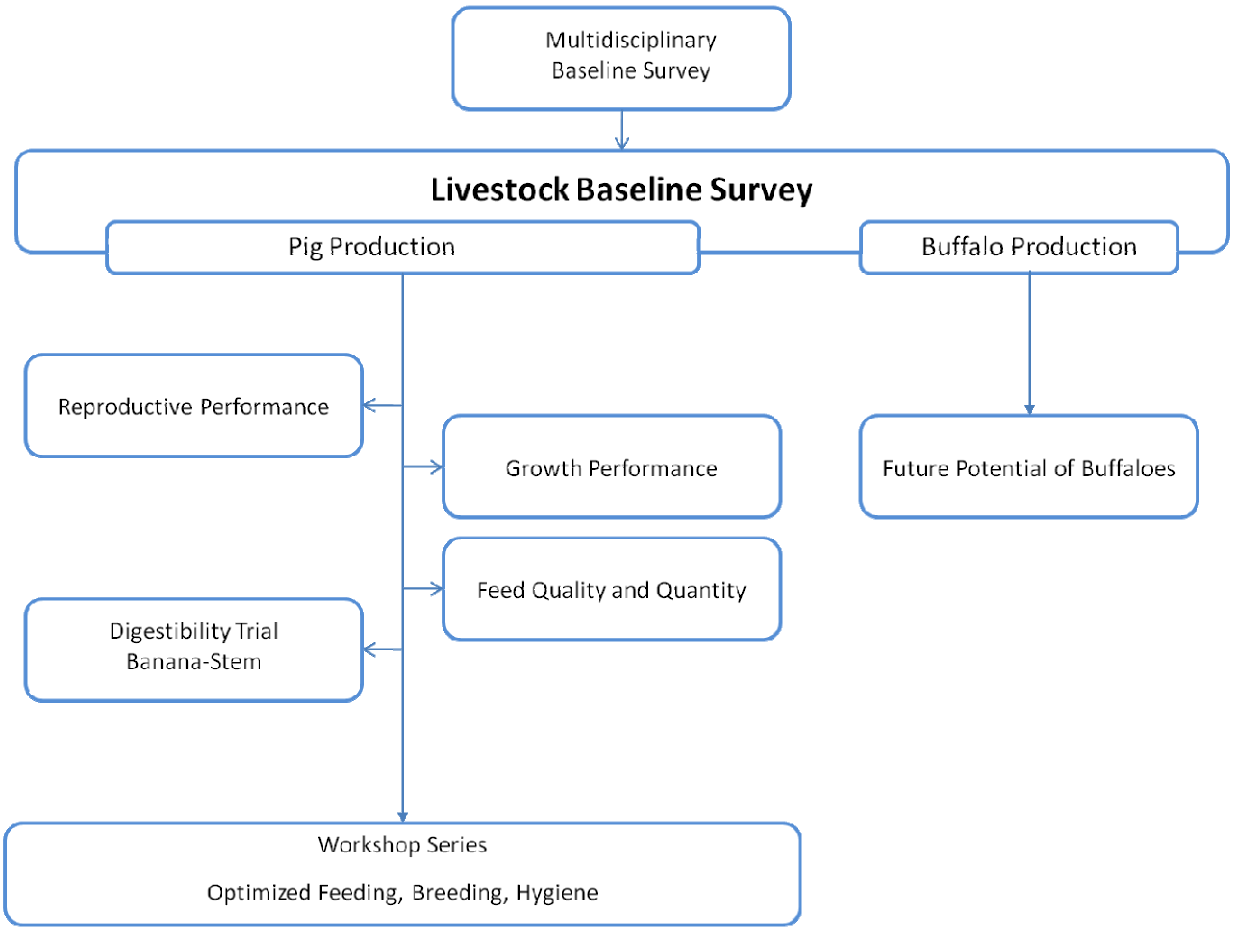

Figure 2: Structure of data collection

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Opportunities and challenges for smallholder pig production systems in a mountainous region of Xishuangbanna, Yunnan Province, China

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Abstract

China’s small-scale pig keepers are the largest community of pork producers worldwide. About 56% of the world's pigs originate from such systems, each producing 2 - 5 head per year. This study analyzes pig smallholders in Xishuangbanna, a prefecture of Yunnan Province. Categorical principal component analysis and two-step cluster analysis were used to identify three main production systems: Livestock-corn based (LB; 41%), rubber based (RB; 39%) and pig based (PB; 20%) systems. RB farms earn high income from rubber and fatten 1.9 ±1.80 pigs per household (HH), often using purchased feeds. PB farms own similar sized rubber plantations and raise 4.7 ±2.77 pigs per HH, with fodder mainly being cultivated and collected in the forest. LB farms grow corn, rice and tea and keep 4.6 ±3.32 pigs per HH, also fed with collected and cultivated fodder. Only 29% of all pigs were marketed (LB: 20%; RB: 42%; PB: 25%), although local pig meat is highly appreciated in the nearby town. An average annual mortality of 4.0 ±4.52 pigs per farm (LB: 4.6 ±3.68; RB: 1.9 ±2.14; PB: 7.1 ±10.82), low reproductive performance and widespread malnourishment are the systems' main constraints. Basic training in hygiene and reproduction management could significantly increase production; most effective measures would be counterbalancing seasonal malnourishment and exploration of locally available protein feeds. Through support by external expertise farmers could more effectively trade their pigs at lucrative town markets.

Introduction

Triggered by China’s tremendous economic development, the country’s livestock sector currently undergoes a massive restructuring. Consumption of meat increased by 230% between 1995 and 2008 (FAO 2010), with a net import close to zero (0.1%; Delgado et al., 1999). Secondary literature suggests that small-scale farms with an output of less than 5 pigs per year supply 50 – 80% of the total of consumed pigs in China (Somwaru et al., 2003; Neo and Chen 2009; State Statistical Bureau 2009). International multi-billion-dollar investments in industrialized pork production (Telegraph 2008; AgFeed 2010), however, put heavy pressure on small-scale producers; Gura (2008) assumes a sevenfold growth rate of intensive pig production systems compared to smallholder systems. Yet, Somwaru et al., (2003) reported that commercial farms contributed only 4.7% to China’s pork production in 2002, while demand growth is ”still on the fast track” (Ma Chuang, vice secretary-general of the China Animal Agricultural Association; Yuanyuan 2010) and will further increase (Delgado et al., 1999; Devendra 2007). The economic transition of very poor rural inhabitants to poor ones produces new livestock keepers and substitutes emigrating farmers. The ongoing trend towards improved productivity (Delgado et al., 1999) and higher earnings from pig farming will keep the market attractive even for small producers. Despite the expansion of supermarkets into rural towns across the country (Hu et al., 2004) rural dwellers still lack trust in this new system and continue buying their fresh vegetables and meat from local sources; this phenomenon is also observed in mega cities such as Shanghai (Goldman 2000) and Hong Kong (Goldman et al., 1999).

Taken together, these aspects suggest that smallholder pig producers are, and will continue to be, very important for China's meat sector. Their support seems advisable from a socio-economic as well as ecological point of view and requires a sound understanding of these systems. To contribute to this task, the present study analyzed the general characteristics and pig management of smallholder pig farms in mountainous areas of southern Yunnan Province so as to identify support strategies that could assist their economic and ecologically sustainable development.

Materials and Methods

Location

The study was conducted in Xishuangbanna Dai Minority Peoples Autonomous Prefecture, which is located in the very south of China, bordered by Laos and Burma. The prefecture is covering an area of 19,223 km^2, of which about 80% range between altitudes of 800 – 2,500 m a.s.l. and 91% of the area is classified as mountainous. The Mekong River separates the prefecture into two regions. Monsoon-dominated climate (avg. annual temp. 24°C and 2600 mm of rain between May and August) prevails in the lowlands while the highlands are slightly cooler and dryer. Annual temperatures range between 18.1 - 21.7°C and annual rainfall is between 1,200 – 1,600 mm, with 90% of rain falling in the monsoon season (May – October). At higher altitudes, temperatures can drop as low as 4°C during winter nights. No extraordinary weather fluctuations were observed during the five years preceding this study.

The prefecture hosts a total of 830,000 people from 14 different ethnic groups; the capital and major town is Jinghong with estimated 400,000 inhabitants. Two smaller towns are Meng Hai and Mon Son with about 50,000 inhabitants each. Dai people account for 34.8% of the total population, other major minorities are the Hani (or Aka), Lahu and Bulang. Most of these groups are transboundary and their settlements spread throughout Laos, Burma, Vietnam and Thailand. Their remote habitations across country borders make them very traditional tribes with own languages and cultural particularities of festivals, clothing and art. The area's isolation has a major effect on its nature as well: due to its unique but seriously threatened rainforests, Xishuangbanna belongs to the most important biodiversity hotspots of the world (Myers et al., 2000).

Agricultural production

Integrated buffalo-rice farming systems with few additional crops and livestock that are typical for rural South East Asia (Devendra and Thomas 2002a) were prevalent for ages in Xishuangbanna. Land use changes started in the early 1970s when rubber tree (*Hevea brasiliensis* Müll. Arg.) plantations were setup in the lowlands. Land privatization in the 1980s plus continuously growing heavy industries that demanded natural latex, and a sense of entrepreneurship of the tribal people in the area (Sturgeon 2010) lead to constant expansion of the plantations for the last 30 years. Today, every piece of land that is suitable for rubber cultivation, by land use laws and biophysical conditions, is planted to *Hevea* trees. The development had a tremendous impact on farmers' socio-economic status but also induced massive degradation of the region's natural resources (Qiu 2009). Natural forest areas in Menglun Township of Xishuangbanna declined from 48.7% to 31.1% between 1988 and 2006 (Hu et al., 2008). Areas exempted from rubber cultivation by law (e.g., rice terraces are not allowed to be turned into perennial cropping areas) are today planted with tropical fruits. Currently banana (*Musa acuminata* Lacatan) and melon (C*itrullus lanatus* Thunb.) plantations are dominating such lands. In the uplands (above 1,000 m a.s.l.) the rubber tree cannot be grown due to its sensitivity to lower temperatures (Rao et al., 1998; Guo et al., 2006). There, highly integrated crop-livestock farms, sometimes combined with aquaponics (Yongneng et al., 2006), still persist. Major upland crops are tea, corn and rice, while fiber-hemp has been introduced through a private company in some villages in 2008.

Due to the focus on latex production, livestock production lost its regional importance. Swamp buffaloes (*Bubalus bubalis carabanesis* L.), formerly kept as transport and draft animals, are largely replaced by small tractors. Most pork and chicken meat offered at local wet markets originates from large-scale farms of 200 km distant Simao town or smaller-scale intensive systems around Jinghong. However, the production of local chickens and pigs is still ongoing in remote areas. The so called 'Yunnan short eared pig' or 'Small Ear Pig' (SMEP; DAGRIS 2007), one of the nine recorded indigenous breeds of southern China (FAO 1984) is often kept in the traditional mountain farming systems, along with exotic breeds, mainly Large White and local X exotic crossbreds.

Data collection

Data on rural farming systems were collected in the Naban River National Nature Reserve (NRNNR), about 30 km northwest of Jinghong. In an area of 26,000 ha, 24 villages are distributed in valleys and mountains between 450 – 2,300 m a.s.l.. The policy of the reserve follows the UNESCO "Men-Biosphere" (MEB[4]) approach and apart from the strictly protected core zone (3,900 ha) land is relatively free of restrictions. The reserve represents a cross-section through the prefecture's total population and agro-ecological systems, with commercial rubber farms in the valleys and subsistence farming at higher altitudes. A household survey was conducted between January and May 2008. Interviewed households (HH) were selected through stratified random sampling with altitude classes and ethnic group serving as strata. To this end, the inhabited altitude range (400 m – 1,600 m a.s.l.) was divided into three classes of equal range (400 m): Lowland (L) was defined as land between 400 - 800 m a.s.l.; midland (M) ranged from 801 - 1200 m a.s.l. and highland (H) was defined as land above 1,200 m a.s.l.. Distinguished ethnic groups were Han, Dai, Lahu, Hani, and other minor groups (H, D, L, Ha, O). Since not all ethnic groups were present at each altitude zone, 13 combinations of altitude x ethnic groups were differentiated. Of each of these categories, 13 - 17 farms were included in the survey, resulting in a total of 208 datasets. Road bias was avoided by randomly choosing target households on village maps. The survey consisted of sets of questions about socio-economic characteristics (such as household size, ethnic affiliation, literacy rate, non-farm income, ownership of fuel-driven machines), plant production (kind and size of cultivated plantations), livestock species and breeds kept, and pig management (feeding, breeding, health care, and culling strategies). Structured open interviews with key persons or institutions, such as the Department for Livestock Development of the Agricultural Bureau of Xishuangbanna, governmental veterinarians, livestock product suppliers and group discussions with farmers and local community development authorities provided additional information.

Data analysis

To identify different production systems we used a clustering procedure which aimed at identifying separating characteristics and sorting farmers into different production classes. One HH was therefore defined as one case. All variables were coded into numbers, whereby scaled variables were kept in their original state and two-class nominal characteristics (male/female, have pigs yes/no, have tractor yes/no) were coded into binaries. Each qualitative trait with more than two

[4] http://www.unesco.org/new/en/natural-sciences/environment/ecological-sciences/man-and-biosphere-programme/

expressions (such as village, ethnic group) was coded into a nominal categorical scheme where one numeric character represents one trait expression.

Household data with many missing values (7 cases) and with an illogical combination of values (6 cases; for example if total cultivated land = 10 ha and sum of individual fields = 12 ha) were excluded. Finally, 184 datasets were chosen for further analysis. All steps of data analysis were performed with PASW 18 (formerly SPSS 18; SPSS 2010).

While good clustering algorithms for either scaled or categorical variables exist, few can handle mixed datasets. Among these are (i) the K-mode (Huang 1998), an adoption of the popular K-Means algorithm, which requires a sensitive *a priori* weighting of variables; (ii) a variation of the successful BIRCH algorithm (Zhang et al., 1997), which was modified to cope with multi-attribute data (Chiu et al., 2001); (iii) the Hierarchical Clustering that only works with categorical data and requires a pre-defined number of clusters; (iv) the two-step clustering approach developed by SPSS (SPSS 2007). Two-step clustering is a much automated system well-suited for identifying an adequate number of clusters and coping with multi-attributed and multi-distributed datasets (Bacher et al., 2004). Additionally, it does not depend on specific distributions of input variables (SPSS 2007). Two-step clustering was therefore chosen for farm type classification in the present study, applying the subsequent steps of pre-selection of relevant variables and of clustering.

The pre-selection of variables that potentially contribute to a meaningful differentiation of farm types was performed using a mixed expert/computer based distinction between blurring and cluster-contributing variables (Vyas and Kumaranayake 2006). Categorical Principal Component Analysis (CatPCA) was used as supporting computer-based method for pre-selection since its algorithm is strongly related to K-Means clustering (Liu and Ozsu 2009), the core of the SPSS two-step cluster analysis.

From the pre-selection the following variables were maintained for further analysis: land use, represented by the variables field size (cultivated area in 2007, hectares) of rubber, tea, corn, hemp and rice. Socio-economic variables were family size (scaled variable), off-farm income (scaled), distance to town (scaled) as well as altitude class, and ethnic group as ordinal categorical variables. Indicators for animal husbandry were numbers of pigs, buffaloes and chicken, which were converted into Tropical Livestock Units (TLU, animal equivalent of 250 kg live weight; 1 TLU = 0.83 buffalo; 10 pigs; 100 chicken). Indicators for the intensity of pig keeping were *"controlled mating"* and *"use of commercial feedstuffs"* (binary variables). Additionally, each production branch was added as binary code, such as *"has pigs yes/no"*. The variables with an absolute component loading (Eigenvalue) greater than 0.5 were: *keep_sow_yes/no*, *TLU_pig*, *TLU_buffalo*, *size_of_corn_fields*, *altitude_class*, *size_of_tea_plantation* and *size_of_rubber_field.*

Figure 3 presents these variables in a two-dimensional chart; a larger distance of a variable to the center indicates a higher significance for cluster building, and a larger distance between two variables indicates a lower correlation between them. Size of rubber plantation, livestock numbers and corn field size were not correlated and had a strong impact on farming systems characteristics. Other indicators of plant production as well as socioeconomic variables had little or no farm-separating impact and consequently were omitted from the further clustering process.

Clustering was then performed to identify the most powerful discriminating variables and appropriate number of classes, in order to assign individual farms to the created clusters (Table 1). Starting with the seven most meaningful variables (Figure 3), the two-step clustering successively eliminated the variables with the lowest impact on cluster creation until a sound equilibrium between the number of variables and the cluster quality ("silhouette measure of cohesion and separation" with -1.0 to 0.2 = poor; 0.21 to 0.5 = fair; 0.51 to 1.0 = good) was found with five variables (*has_buffalo, has_sow, corn_ha, rubber_ha, tea_ha*), leading to a separation of 3 clusters and an average silhouette measure of 0.6 (Table 1). Since the applied clustering algorithm is sensitive to the order in which variables are entered into the model (Bacher et al., 2004), different entry orders were tested but did not generate different results.

Table 1: Cluster-determining variables identified through categorical principal component analysis (CatPCA) and two-step cluster analysis for grouping 184 households (HH)into three main production systems

		Cluster		
Trait	Unit	1	2	3
Has buffalo (yes)	% of HH	100	0	0
Has sow (yes)	% of HH	86	0	92
Corn area	ha	0.49	0.09	0.19
Rubber area	ha	0.54	2.05	1.81
Tea area	ha	0.52	0.1	0.7
Major agricultural activities		Buffalo-Pig-Corn	Rubber	Pig Rubber

Each cluster was finally named after its major agricultural activity (Table 1): Livestock-corn based (LB), pig based (PB) and rubber based (RB). Although PB farms owned similar sized rubber fields as RB farms, these were not considered for naming since they mostly still were in preparation (and take >7 years until first latex harvest). Simple descriptive statistics and ANOVA followed by

Tamhane *post hoc* testing (conservative pair-wise comparisons test based on t-test; SPSS 2007) were used to compare the final farm clusters; significance was declared at P<0.05.

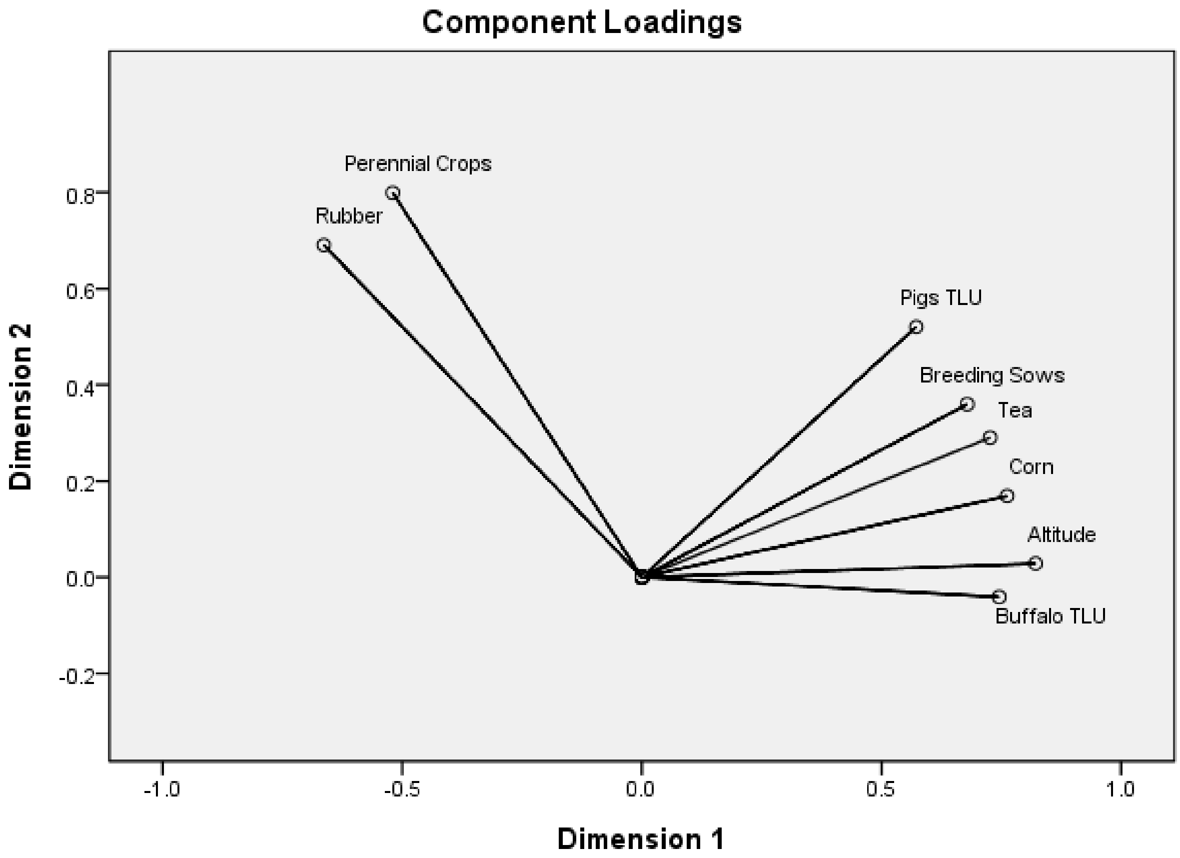

Figure 3: The Impact of Variables onto Cluster-Creation. Outcome of the Categorical Principal Component Analysis

Distance to center (x=y=0) indicates relevance of variable for cluster creation (larger distance = higher relevance), and distance between two variables indicates their degree of correlation (larger distance = lower correlation).

Crop areas in hectares; buffaloes and pigs in TLU; breeding sows as binary "yes/no" , altitude (m a.s.l.) in three classes (1: 400-800 m a.s.l.;2: 801-1,200 m a.s.l.; 3: >1,200 m a.s.l.).

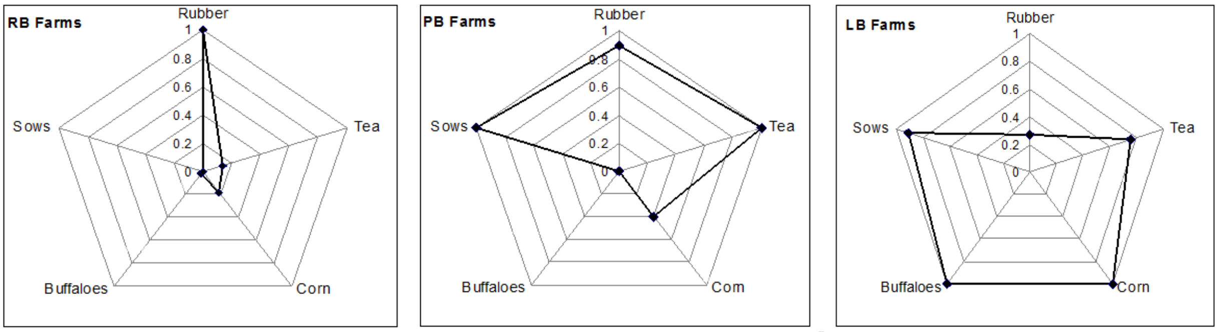

Figure 4: Production diversification of three farm types.

Each dot in the spider web displays the relative importance of one production branch whereby 1 is equivalent to the highest relative possible expression of a trait found in the total population, and a broad web indicates a higher level of diversification.

Example: PB farms, compared to RB and LB farms, have the highest average tea field size (0.890 ha), their relative tea-score was set to 1. In comparison, average tea-field size on LB farms is 0.531 ha, which is 60% of PB tea-field size, consequently their tea-score is 0.6.

Results

General farm characteristics

Three main production systems were identified, namely livestock-corn based (LB), rubber based (RB) and pig based (PB) farms, reassembling 76 (41.3%), 71 (38.6%) and 37 (20.1%) of the 184 HHs (Table 2; Table 3). Across these three farm types, time to reach Jinghong with a motorbike averaged 1.9 ±0.75 hours (range: 0.8 - 3.5 hours). Farm size averaged 2.7 ±2.00 ha and varied from 0.1 - 14.7 ha. The four dominant tribes in the region were Han, Dai, Hani and Lahu (in decreasing order). All HHs were headed by an adult male and consisted of one to nine individuals. Almost half of the HH members (0.44) were literate, but literacy rate ranged from zero to one. In 8% of the HHs at least one person was member of the Communist Party of China.

Fields comprised 0.9 ±1.15 ha of annual and 1.7 ±1.69 ha of perennial plantations (Table 2). Rice and corn were the major staple crops cultivated by 87.5% and 67.4% of HHs; rubber and tea were cultivated by 66.3% and 65.2% of the interviewed farmers. An average of 17.9 ±19.01 chickens, 4.0 ±2.88 pigs and 2.0 ±1.24 buffaloes were kept by 92.4% chicken keeping, 89.1% pig keeping, and 41.8% buffalo keeping HHs. Animal manure was used by 77.2% of all HHs to fertilize vegetable gardens (54.2%), rice fields (47.2%), rubber fields (38.0%), and to feed biogas fermenters (38.7%) providing light and fuel on the farm.

Table 2: Characteristics of farm households (HH); cropland area and mammalian livestock of three main farm types

Farming system	Altitude[1] % of HH		Ethnic Group[2] % of HH		Crops[3]	Area (ha)	SD	Livestock[3, 4]	TLU (n)	SD
All (n=184)	Lowland	48.9	Han	21.2	Rubber	1.38	1.675	Buffaloes	0.85	1.287
	Midland	22.8	Dai	19.6	Corn	0.28	0.332	Pigs	0.36	0.301
	Highland	28.3	Lahu	39.7	Tea	0.39	0.591	Sows	0.06	0.065
Livestock-corn based LB (n=76)	Lowland	22.4	Han	19.7	Rubber	0.55 [a, b]	0.940	Buffaloes	2.03 [a, b]	1.275
	Midland	26.3	Dai	2.6	Corn	0.49 [a, b]	0.375	Pigs	0.93 [a]	0.665
	Highland	51.3	Lahu	57.9	Tea	0.52 [a]	0.531	Sows	0.19 [a]	0.119
			Hani	19.7						
Rubber based RB (n=71)	Lowland	84.5	Han	12.7	Rubber	2.05 [a]	1.901	Buffaloes	0.04 [a]	0.203
	Midland	9.9	Dai	46.5	Corn	0.09 [a, c]	0.155	Pigs	0.39 [a, c]	0.360
	Highland	5.6	Lahu	29.6	Tea	0.1 [a, c]	0.216	Sows	0 [a, c]	0.000
			Hani	8.5						
Pig based PB (n=37)	Lowland	35.1	Han	40.5	Rubber	1.81 [b]	1.683	Buffaloes	0 [b]	0.000
	Midland	40.5	Dai	2.7	Corn	0.19 [b, c]	0.220	Pigs	0.96 [c]	0.554
	Highland	24.3	Lahu	21.6	Tea	0.69 [c]	0.890	Sows	0.21 [c]	0.100
			Hani	32.4						

[1] Altitude: lowland = 400-800 m a.s.l.; midland: 801-1,200 m a.s.l.; highland > 1,200 m a..sl.

[2] Ethnic group: difference to 100% is due to some more minor ethnic groups.

[3] Letters indicate statistical differences between group means ($P<0.05$): [a] LB *versus* RB; [b] LB *versus* PB; [c] PB *versus* RB

[4] TLU: Tropical livestock unit; equivalent of an animal of 250 kg live weight (buffalo = 1.2 TLU; pig/sow = 0.2 TLU).

SD standard deviation

Table 3: Selected socioeconomic characteristics of farm households (HH)

Farming system	Distance to Town[1]		Literacy Rate[2]	Household Size		Non-Farm Income[3]	
	Hours	SD	% of HH members	Persons	SD	% of HH	Range
All (n=184)	1.9	0.75	44%	4.62	1.97	15%	1,800-50,000
Livestock-corn based **LB** (n=76)	2.3	1.92	38%	4.9	1.45	11%	2,400-12,000
Rubber based **RB** (n=71)	1.6	0.70	48%	4.5	1.59	17%	7,400-50,000
Pig based **PB** (n=37)	2.2	0.57	54%	5.2	1.69	24%	1,800-24,000

[1] Unit: Average driving hours by motorbike during dry season from village center to the closest market in town

[2] The percentage of household members who finished primary school education

[3] Numbers were taken as provided during interviews and are not based on actual calculations, expressed in Chinese RMB (10 RMB ~ 1 EUR)

Table 4: Characteristics of pig management in smallholder pig farms

Farming system	Sows per HH[1] Average	Sows per HH[1] % HH	Free Range Period Months $year^{-1}$ Mean	Free Range Period Months $year^{-1}$ SD	Popularity of Pig Feed Component	Popularity of Pig Feed % of HH	Utilization of Pigs Utilization	Utilization of Pigs % of Pigs
All (n=184)	0.30	53	1.9	1.23			Self consumed	71
							Sold	29
Livestock-corn based LB (n=76)	0.95	86	1.9	0.43	Banana pseudo stem	98	Self consumed	60
					Corn	95	Sold	20
					Meal leftovers	87	Gifted	20
					Commercial feed	7		
Rubber based RB (n=71)	0.00	0	1.2	0.38	Banana pseudo stem	73	Self consumed	57
					Rice bran	86	Sold	43
					Corn	79		
					Commercial feed	30		
Pig based PB (n=37)	1.10	92	2.0	1.10	Banana pseudo stem	87	Self consumed	75
					Corn	97	Sold	25
					Meal leftovers	89		
					Commercial feed	19		

[1] HH = Households

After cereal harvest in September/October, 44.4% of pig keepers let their pigs scavenge freely in the village and forest for 1.9 ±1.23 months per year (range 1 - 10 months). However, free ranging of pigs has strongly decreased due to increasing conflicts between pig (and buffalo-) keepers and cash crop farmers/companies in the area, and is expected to vanish in the near future. Pigs were fed with a variety of at least 18 different feedstuffs, whereby banana pseudo stem, rice bran, corn and "green plants from the forest" were the most widely used (Table 4). Feed composition depended on the availability of fodder plants and varied strongly between seasons. Pig feed was prepared as a batch for 2 - 5 days and offered from this pool twice daily. Watering was done by dilution of the feed ration; no additional watering occurred. Commercial feeds such as fishmeal were used by 17.3% of pig-keeping HHs. The daily work of pig feeding was done by women and sometimes children, but the decision to purchase, sale and slaughter pigs remained with the HH head. Piglets for fattening were purchased from traders or from highland farmers by 48% of the pig keepers; the other 52% pig-keeping HHs were breeders keeping sows. Few pig keeping HHs (2.5%) kept breeding boars; most sows mated randomly with boars from the village or wild boars in the forest during scavenging periods. Among the pig breeders, 30.5% were actively choosing a mating partner for their sows, the remaining farmers relied on random mating. Local SMEP was the dominant breed, followed by crosses and exotic breeds. However, all farmers tended to call their pigs SMEP regardless of breed, since SMEPs yield high prices on local markets. In the 12 months preceding our survey, 60% of pig keeping HHs encountered pig diseases – in 70% of these cases at least one pig per farm died. In 76% of all disease occurrences the owners could not identify the disease or the reason of death. Governmental veterinarians assisted farmers in 65% of disease outbreaks.

The overall share of sold animals in total pig off-take was 29%, but only 2.2% of all pig farmers stated to earn their major income from pig production (Table 4). According to group interviews, the main constraints of pig production were high disease-related losses and lack of labor time to prepare pig feed. For some farmers lack of money to purchase additional sows was the first limiting factor. The majority of pig keepers was interested in intensifying pig production to stabilize their income. However, farmers who only fattened pigs were often satisfied with their production and not interested in production increase, although they stated to purchase meat for family consumption because the latter exceeded their production.

Tea and rubber cultivation were the main income source of 44.6% and 39.7% of farmers, followed by rice (6.0%), corn (5.4%) and other minor income sources. Non-farm income from government employment, unskilled off-farm work or shop keeping was earned by 15% of HHs (Table 3) and ranged from 1,800 - 50,000 RMB per year (10 RMB = 1 €). However, there was no family with more than one member earning non-farm income. High-value assets such as a motorbike or a tractor, respectively, were owned by 82% and 60% of all HHs.

Livestock-corn based farms

The main characteristics of LB farms were their location at high altitudes, mainly Lahu tribe affiliation, and low literacy rate. While 52% of LB farms were found at >1,200 m a.s.l., 22% were situated between 400 – 800 m a.s.l. and 26% at 801 – 1,200 m a.s.l.; distance to Jinghong varied between 1 - 3.5 hours of motorbike drive. Lahu minority (57%) dominated on LB farms, followed by Han (20%), Hani (12%) and others, with an average of 4.9 ±1.45 members per HH. Almost half of LB HHs (47%) had a low literacy rate with at maximum 50% of HH members able to read; in 26% of LB farms no HH member was able to read. Eleven percent of LB HH earned a non-farm income from jobs in the "service industry" and as "government employees" (such as "forest protector" or "party secretary"), yielding 25,000 ± 38,900 RMB per year (range 2,400 - 120,000); 8% of LB farmers refused to state the origin of their non-farm income.

LB farms owned 2.5 ±2.07 ha of agricultural land planted to corn (22.2%), tea (21.2%), hemp (19.4%), rubber (18.4%), and rice (13.5%). However, 63% of LB farmers did not own rubber plantations. All LB farms kept 2.0 ±1.27 buffaloes, 94.7% kept pigs (4.6 ±3.33) and chicken (13.5 ±12.68). Pigs were kept in wooden/bamboo or sometimes brick-made pens for most of the year. Sixty-seven percent of LB pig keepers let their pigs scavenge freely for one (14%), two (43%) or three (10%) months per year after harvesting time. The main pig feed components used were banana pseudo stem, corn, meal leftovers, rice bran and different wild grasses from the forest, fed by 98.6%, 95.8%, 87.5%, 62.5%, and 61.1% of LB pig keepers; 7% fed purchased concentrates such as fishmeal. At the time of interview, only 82% owned sows but all LB pig keepers stated to generally breed their own offspring. While 71% of pig keeping LB farmers kept one sow, 10% had two or more breeding sows and 3% kept a breeding boar. Only 20% were actively choosing a mating partner for their sows, the other LB pig farmers let their sows mate randomly during free ranging periods. Maintaining the gene pool of SMEP by using only SMEP boars for breeding was the desire of 15% of LB pig farmers. Although a general definition of SMEP characteristics could not be obtained from these respondents, no farmer desired to introduce exotic genes into his herd. Important traits for boars were strong (15%) and large-scaled frame (13%), but 80% of the LB pig keepers did not prefer any trait. Diseases in their herds had been recognized by 70% of all LB pig keepers during the 12 months preceding the interview. Mortality ranged between 0 and 100%, and on average each farm had lost 4.6 ±3.68 pigs due to diseases in the previous 12 months. Disease-affected pig farmers lacked knowledge to identify diseases but named anorexia (76%), no thirst for water (73%), diarrhea (14%) and fever (11%) as signs of diseases in a multiple answer sheet. Of the pigs that were taken out of the herd (total exits minus unintended such as disease, lost, theft), 20% were traded and 20% of pig owners gifted at least one pig to another person – the rest was self consumed. However, 51% of the farmers stated to never sell pigs and 66% had not sold any pig in the past 12 months. Of the sales 26% were made to traders who visited the villages, and 9% to farmers in villages close to Jinghong; all other sales took place in the neighborhood of the farm. LB farmers were very interested in expanding their pig production and frequently asked for support in education and investment. For them massive disease problems, ineffective support by governmental veterinarians and low growth rates of fattening pigs were the main constraints of pig production. Keeping more pigs was desired but limited by lack of labor and capital.

Rubber based farms

Rubber based farms were located at 1.6 ±0.70 hours motorbike travel distance to Jinghong, mainly below 800 m a.s.l. (84% of RB farms). These HHs comprised 4.5 ±1.59 members; 46% of all RB HHs were Dai, 30% were Lahu and 13% were Han. On average 48% of the RB HH members were literate, and 17% of RB HH earned non-farm income (16,000 ±17,400 RMB). Of the total farm land (11.9 ±2.08 ha) 69% was planted with rubber, 15% with rice, 5% with corn and 11% with other crops. Only 2.8% of RB farmers kept buffaloes (Table 2), 53% kept pigs (1.9 ±1.80) and 87.3% had chicken (17.8 ±23.91). Pigs were predominantly kept in concrete stables with iron sheet roofs. 24.5% of RB pig keepers let their pigs range freely during 1 - 2 months per year. Rice bran (86.8%), corn (79.2%), pseudo stem of wild banana (73.6%), small amounts of meal leftovers (73.6%) as well as a diversity of grasses growing in the forest and on field borders (69.8%) were used as pig feeds. 61% of RB pig keepers exclusively used purchased feed, and 30.2% purchased some ingredients such as fishmeal. All RB farmers were only fattening purchased piglets and did not keep sows. Piglets were mainly obtained from commercial breeders in Simao area (app. 200 km north of Jinghong); they were large-framed (adult weight >150 kg) with phenotypic characteristics similar to the local breeds. In the 12 months preceding the survey 28.3% of the pig-keeping RB farms had been affected by pig diseases with a loss of 1.9 ±2.14 pigs on affected farms. RB farmers were also not able to name the diseases but associated the symptoms “anorexia”, “no thirst for water” and “diarrhea” to 54%, 46% and 39% of the disease cases. Of the surviving pigs, 43% were traded, the rest was self consumed. Pigs were mostly (60%) sold to a “trader that came to the village”, the others were sold to villages near Jinghong and Jinghong suburbs; 6% of RB farmers did also give away pigs as gift. Regression analysis between wealth (expressed in *rubber_ha*) and number of pigs (*TLU_pig*) of RB farmers revealed that pigs were evenly distributed among rich and poor RB farmers, with no clumping at farms with less rubber area (Pearson Correlation r = -0.18; P=0.896), indicating that wealthy farmers were not abandoning pig fattening. An open-ended question about farmers' ideas for improvements in agricultural production revealed that no RB farmer desired to expand his pig production.

Pig based farms

Pig based farms were located at 2.2 ±0.57 hours motorbike drive from Jinghong and found at all altitudes (400 - 800 m: 35.1%; 801 - 1,200 m: 40.5%; >1,201 m: 24.3%). With 5.2 ±1.69 members per HH they had the largest families. Main ethnic affiliations were Han (41%) and Hani (32%). More than half of all HH members (54%) were literate. An income of 12,000 ±8,800 RMB per year from non-farm activities was earned by 24% of PB HHs. Executed jobs were "teacher", "trader", and "employment in the service industry", but most persons refused to state the origin of their additional income.

Of the 3.6 ±0.90 ha cultivated per HH, 51% were covered with rubber, 17% with tea, 9% with corn and 8% with rice (Table 2). No PB farmer kept buffaloes, 97% kept 20 ±18.0 chicken and all raised pigs. The average size of a pig herd was 4.8 ±2.77 head. Pigs were mainly housed in wooden pens; 27% of PB farmers let their pigs range freely for about 2 months (median) per year. Fodder was based on corn, meal leftovers, banana pseudo stem, rice bran and different green plants collected from the forest, fed by 97%, 89% 87%, 81%, and 81% of PB farmers. Additionally, 19% of the farmers purchased fish meal. Mostly one breeding sow was kept (92% of PB farmers). While half of the sow-owners let their sows mate randomly, the other half selected the boar for mating. Of the latter farmers, 76% wished to mate their sows with a local SMEP boar, 18% with a crossbreed local X improved boar. The rest preferred other undefined local breeds. Healthy, strong and large-framed were the primary selection criteria for a boar. Half of the RB farmers (49%) reported occurrence of pig diseases in their herd in the past 12 months, with an average loss of 7.1 ±10.82 pigs. Anorexia and "not thirsty" (62.5% each) as well as "lack of energy" and diarrhea (19% each) were the most frequently recognized signs of disease. 25% of the surviving pigs were sold, 47% of them to traders visiting the villages; all others were sold to RB farmers. PB farmers showed interest in expanding pig production but pointed to disease risks and lack of labor for feeding pigs as main constraints to intensified production.

Discussion and Conclusions

The combination of CatPCA with SPSS two-step clustering proved to create meaningful classes and reliably allot farms to these. The semi-automated CatPCA algorithm aided to identify the relevant variables which determine the major agricultural systems in the study region. Similar soundness of the combination of CatPCA with two-step-clustering to classify multi-attributed data in household studies and to create solid and meaningful household clusters was reported by Dossa et al., (2011). The three farm types were significantly different in their setup and management practices. According to Notenbaert et al., (2009) a sound exploration of smallholders' full situations, including social, natural and technical aspects, is required to successfully support their development. One-solution-fits-all approaches as well as targeted interventions to solve one very specific problem failed to sustainably develop such farming systems in the past. Notenbaert et al., (2009) therefore recommended a holistic approach beyond farming systems analysis.

Socio-economic aspects

Summarizing the socio-economic characteristics of the three farm types, more poor self-subsistent farmers were living in the uplands, whereas richer farmers involved in cash-cropping and marked-oriented livestock production predominantly lived in the lowlands. Jalan and Ravallion (2002) also identified the location of a farm in China as a significant determinant for household consumption, and reported the factors *montane_area* and *bad_road_access* to be major inhibitors for increasing consumption. Such areas were therefore named "geographical poverty traps". In the NRNNR, Lahu people are captured in such traps of geographical and cultural distance to town. Du (2000) described the Lahu as "socially weak and uneducated "and "undermined rather than strengthened by the Chinese education system". Due to their social, cultural and geographic remoteness, they lack access to social infrastructure, including markets and education. In contrast, the Dai who are mainly RB farmers, and partially also the Hani who dominate the PB cluster, are mostly living at low- and mid-altitudes, have strong relations to the town and are often involved in trade (Sturgeon 2010). The strength of the Dai originates from their history of ruling the prefecture, whereas Han and Hani have a good sense for business and benefit from strong governmental support. Distance to town of those groups might not always be significantly shorter than that of the Lahu, but their education and pig-marketing strategies as well as the size of land cultivated with cash-crops indicate a better socio-economic status. Central and provincial government acknowledge the "periphery syndrome" of minority people in "periphery areas" and implemented measures such as minority schools, but in reality equal chances of underdeveloped tribes and areas often get stuck at local levels (Hansen 1999; Wang and Zhou 2003).

The small differences in HH size are due to China's one-child-policy, which allows however two children for minorities and farmers. Since children are required for farm labor the policy reduces the chances for farm children to attend higher schools. Under such conditions long-term escape from illiteracy and farming is difficult to achieve, since a non-farming activity is key to escape poverty for small farm households (Xing et al., 2009; Wiggins et al., 2010).

Land cultivation

The variable "having rubber" was a major determinant for the classification of farming systems in the NRNNR, the explanation being the economics of rubber planting. Qiu (2009) calculated a 15-fold higher income per area of land from rubber compared to rice. Once a rubber plantation can be tapped, the labor input for harvesting latex is only a fraction of the labor investment needed for other crops common in the area. Consequently, wherever possible, rubber replaces all other crops, and RB farmers underwent a change "beyond our imagination" (Chen Chin, Director of the Xishuangbanna Tropical Botanical Garden, cited in: Qiu 2009). Between 1998 and 2004 Fu et al., (2009) calculated an increase of the rubber-based income of 438% for some villages in the region. However, rubber is sensitive to global financial markets - the average monthly farm-gate price, as displayed by the Malaysian Rubber Board (http://www.lgm.gov.my/), fluctuated by 300% between 2007 and 2010. In addition, monoculture plantations are highly threatened by disease outbreaks and in the long-term by soil degradation (Wolff and Zhang 2010), which threatens farmers' livelihoods and the region's ecology. Although highland farmers can trade tea under the famous and expensive label "Pu'er", tea prices are also heavily influenced by traders and financial gambling, with farm-gate prices per kilogram of dried "Pu'er" tea fluctuating between 10 and 200 RMB during 2000 - 2010 (Chinaeconomic.net 2007).

Livestock husbandry

Very poor rural dwellers benefit from livestock rearing (Steinfeld et al., 2006) and the combination of plant and animal production has positive effects on the economy and ecology of small farms (Devendra and Thomas 2002b; Gura 2008). Buffaloes have been a major asset in South-East Asian agricultural systems for decades, serving as draft and transport animals with only old animals being culled. In the NRNNR, LB farmers still utilize buffaloes on steep rice terraces where they are easier to manipulate than tractors. Although some RB and PB farmers also still work with buffaloes, buffalo keeping is no more important for these groups. Higher availability of tractors through better infrastructure and economic conditions in the mid- and lowlands decreased the value of buffaloes although their meat is still consumed at religious and family festivals, but is mainly purchased nowadays. Secondly, buffalo keeping requires high labor input: animals are grazed daily and merging of herds is not common (chapter 4). Therefore, if opportunity costs of labor time rise, the costs for keeping a buffalo also increase, making herding more expensive. Thirdly, grazing land is scarce in the lowlands due to the spreading of rubber and recently banana.

Similar to the buffalo, pig keeping is not important as an income source for RB farms, since only a few pigs are fattened, no offspring is produced and often purchased fodder is used. However, pork meat is daily available through traders. One might assume that with increasing wealth, pig keeping, like other non-rubber farming activities, would fully loose its importance. The missing correlation between numbers of pigs and size of rubber fields falsifies this assumption (section Results, 'Rubber based farms'). In China, pig keeping is an old part of culture: Besides the production of pork, pigs were an indicator of wealth and power (Kim et al., 1994), and slaughtering of pigs is a central part of many cultural and religious events celebrated in the Jinghong region (own observation). In addition, RB farmers have strong connections to the city, where they invest in real estate and maintain contacts to local authorities. In such relations a frequent gifting and bribing is very common (Millington et al., 2005). In fact, most pig deals of RB farmers were done with partners who were close to or from the city. The high number of chicken was kept for the same reason - RB farmers often received visitors or businessmen from town and offered their guests a meal of freshly slaughtered chicken. Despite significant economic and ecological benefits from combining livestock and rubber farming (Paris 2002), incentives for integration are low compared to the earnings from rubber alone in the target area. As a consequence, pig keeping will certainly endure in RB farms as a strong element of local culture, but this system offers no potential for an increase in pig production due to its low contribution to overall farm economics. In the future RB farmers might rather shift even stronger to buying piglets or fattened pigs from LB and PB farms.

Pig husbandry

While farmers reported to have their pigs scavenge freely for almost the whole year in past times, the risk of destroying high-value cash crops nowadays forces them to keep pigs in pens. Whereas RB and PB farmers tended to use more purchased fodder, LB farmers mainly utilized self-cultivated or collected feedstuffs. Similarly to the latter, smallholders all across Laos, Vietnam and Cambodia collect leaves of wild plants and use cultivated plants such as corn, and by-products such as rice bran to feed their pigs (Hai and Pryor 1996; Loc et al., 1997; Rodríguez and Preston 1997). Such management requires high labor input for fodder collection and preparation (2-3 hours per day; Stür et al., 2002), and diets are often energy-rich but protein deficient (e.g., Loc et al., 1997; Rodríguez and Preston 1997).

Among the most important pig feed components in NRNNR was banana pseudo stem that is also commonly used in Vietnam, Laos and Thailand (Toan and Preston 2007; Haußner et al., 2009). Depending on the plant species, which was not determined in our study, the crude protein (CP) concentration varies between 20 - 64 g CP kg^{-1} DM and the dry matter (DM) content ranges from 5.1 - 9.5% of fresh weight (Göhl 1981; Chedly and Lee 2000; Kumaresan et al., 2007). Similarly, "green plants from forest and fields" are fed to pigs across South East Asia (Stür et al., 2002; Haußner et al., 2009; Phengsavanh et al., 2010). While those plants were not individually identified in our study, Phengsavanh et al., (2010) determined 12 - 35 g CP kg^{-1} DM, but assumed a low digestibility due to high fiber content in pig fodder plants from Northern Laos, which is in ecological and geographic proximity to NRNNR.

Lack of appropriate fodder, whether seasonally or year-round, impacts the productivity of the whole systems: pigs fattened in a period of feed abundance not only lose weight during periods of feed scarcity but also suffer from higher disease susceptibility and reproductive failure (Stür et al., 2002). Better utilization of available feeds combined with efforts to make new ones available might therefore have the strongest impact on productivity (Thomas et al., 2002). However, available literature only points to general pathways for improved feeding. Therefore a more detailed analysis of farmers' feeding practices, the used feedstuffs and the seasonal patterns of nutrient supply could identify bottlenecks and suitable feeding systems for pigs in the NRNNR and adjacent areas.

Our survey also revealed profound shortcomings in knowledge about livestock diseases. Only 24% of disease-affected pig farmers named diseases that occurred in their pigs, but most of them referred to "swine-flu" which had been prevalent in China before interview time. The most frequent descriptions of diseases were "pig did not eat and died" and "pig did not stand up and died". The veterinary service was well organized in NRNNR, with one governmental vet assistant being responsible for each village. These assistants were accepted by the farmers and regularly visited the farms for government-supported vaccination campaigns and emergency treatments. However, success was moderate since most diseases recognized by the farmers were lethal to most of the pigs. Interviews with the vet assistants (n=4) also revealed substantial lack of knowledge. Diseases and treatments could not be described precisely, they only knew how to apply an "injection" to "a sick pig” or as “disease prevention” to healthy pigs, with no further knowledge about common diseases or their symptoms.

The high mortality rates determined in this study might not be representative since an epidemic disease spread in China and neighboring countries in 2007 and 2008 and, compared to numbers from 2006 and 2008, lowered China’s annual production of pig meat by 9% (FAO 2010). On the other hand, pig farmers in the highlands of Laos were reported to often experience epidemic pig diseases that killed most pigs in a single outbreak (Stür et al., 2002). A high disease incidence therefore is common in the region. Besides lethal diseases, farmers reported high numbers of gastrointestinal helminths in slaughtered pigs, but lacked knowledge about their origin, impact and prevention measures. Effective disease prevention is therefore another key issue for improving pig production in Xishuangbanna. Although institutional capacities exist and might be able to cope with such challenges, the flow of knowledge about animal hygiene and management to smallholders in remoter villages seems to be a bottleneck for progress.

Pig marketing strategies

The previous sections pointed to major constraints for pig production, limiting the yearly output of pigs to what is sufficient for home consumption and sporadic sales. After resolving the major shortcomings of feeding and health care, the implementation of an effective marketing strategy for the SMEP would help farmers to increase their income and expand their shock-absorbing capability (Perry et al., 2002). While wet markets in Jinghong were the best marketing places for smallholders in the past, the number of western-style supermarkets in the town grew from 2 to 7 between 2008 and 2010 (own observation). No supermarkets existed some 30 years ago but they spread quickly in all parts of China after implementation of the “Opening to the West” policy (Hu et al., 2004). Guarantee of food safety, a growing wealthy consumer class and rising opportunity costs for female spare time lead to the preference of supermarkets over local markets by an increasing number of customers (Hu et al., 2004). These authors also report about a countrywide law and its starting implementation, that aims at turning ”unhygienic wet-markets” into supermarkets. Based on studies from emerging South American countries, Hazell et al., (2010) argued that tropical smallholders successfully provided high-quality export goods some 50 years ago and can still do so today, but they are disadvantaged by large-scale factory-like production. In Xishuangbanna the government recently developed a marketing strategy for SMEP which seeks to set up a supply chain, from producers to shops, for selling 100,000 head of SMEP per year in the whole province (Neo and Chen 2009). The approach seems promising since well-off Chinese have a strong preference for ecologically produced food. All larger supermarket chains in China offer labeled organic food products (Paull 2008), and the market for eco-vegetables is growing quickly (Hoering 2009; FAO 2010; Hoering 2010; Hoering and Gura 2010). A Shanghai-based company (Jilin VITALE Organic Agricultural Co. Ltd.; http://www.ejqs.com/en) successfully markets organic meat of the "Black Mountain Pig" from small-scale farms, which increased the company's inland business volume by 50% to 11 Mio RMB between 2005 and 2008 (Anonymous 2008).

In Jinghong at present one single "Small Ear Pig Shop" exists that offers SMEP meat and eggs from local sources. The turnover is 2 - 3 pigs per day. In 2009 the shop-owning company started so called "company-cooperate-farming contracts" where farmers raise SMEPs with piglets and fodder provided by the company. For each successfully raised pig farmers earn 100 RMB (shop manager, personal communication). The company also guarantees to sell original SMEP meat and offers tenfold compensation to customers in case of "counterfeited meat". An unpublished study (Qian 2009) on the perception of organic food among Jinghong inhabitants (n=201) revealed that 84% of the citizens know and prefer SMEP meat over regular pork, but only 23% regularly consume it. The other respondents argued that the "price is too high" and the meat is "not available" as hindrances to regularly purchase SMEP meat.

The recent development indicates that there is a realistic chance for NRNNR pig farmers to market their products. While RB farms may lack incentive to take up to pork marketing, PB and especially LB farmers could significantly improve their livelihoods through this new marketing opportunity. However, access to the market and proper information is a big challenge to them (IFPRI, 2005). The frequent "random farm gate selling to mobile traders" points to the farmers' disadvantage vis-à-vis middlemen, and Samkol et al., (2006) described such farmers as rather being "price takers" than "price makers". The formation of cooperatives and similar groups, or avoidance of middlemen by establishing direct business relations with retailers would strengthen small-scale farmers. However, such incentives are far beyond the capacity of geographically and culturally remote pig producers and require substantial external support.

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The productivity of traditional smallholder pig keeping systems and possible improvement strategies in an area of Xishuangbanna, southwestern China

Abstract

Chinese smallholder pig producers, only outputting few pigs per year, still supply the major portion of pork consumed in the country. While most research and policy focuses on large scaled intensive holdings, small scale pig production – although being considered ineffective and not competitive – is an important economic factor for reduced rural poverty, bears the potential of environmentally friendly meat production and further, is a potential supplier for the massively growing Green Food sector in China. This study was carried out to analyze the factor productivity and reproductive performance of 162 traditional smallholder pig producers in a 50 km² area of Xishuangbanna, Yunnan, southern P.R. China, by using the PRY Herd Life Model. The analysis of the actual and two simulated improved pig management scenarios reveals the current productivity and possible enhanced outputs of the system. A progeny history survey covering 184 sows and 437 farrows, combined with an analysis of the quantity and quality of feed given and of live weight (LW) development of 114 pigs during a 16 months time period served as data basis. Feed energy content averaged 14.92 MJ ME kg DM^{-1}, first farrowing age was 14.5 ± 4.34 months, inter-farrowing interval was 11.4 ± 2.73 months. A litter comprised 5.8 piglets and was weaned after 4.3 ± 0.99 months. Monetary returns on investments (ROI) was negative for the current production conditions (1:0.67), but improved (1:1.2) when culling management was optimized for highest output per feed input. If in addition better feeding, controlled mating and better resale prices at fixed dates were simulated, ROI substantially improved to 1:2.45, 2.69, 2.70 and 3.15 for four different grower groups. Results show the potential of pork production for the region in the future, if basic improvement measures are applied. Future exploration of the production conditions, including climate, market-season and culture, is required before initiating the recommended measures to ensure the sustainable development of a more effective and resource conserving pork production in the future.

Introduction

In 2010, China has slaughtered 655 Mio pigs, which was more than half of the world's total production in that year (1.2 Billion; FAO, 2012) and the country's demand for pork is expected to grow further in future years. While an increased share of those pigs originates from large scale industrialized production systems, the majority still is produced in extensive smallholder systems (Somwaru, 2003; CSSB, 2009). In 1999, China's Research Center of Rural Economy estimated that 91.6% of all Chinese pork farms had an output of less than 6 head per year (Somwaru, 2003). Very little is known about these producers, which have long been neglected in favor of large scaled industrialized farms. Generally they are described as poorer households, living of extensive and small-sized crop-livestock husbandry and being located in rural areas all over the country (Qiao et al., 2011; Riedel et al., 2012). No studies are known which deal with such farms' production characteristics or productivity parameters. Studies on South East (SE) Asian smallholder pig producers describe them as having a very low productivity, high mortality rates and suffering from inefficient management (Devendra and Thomas, 2002; Stür et al., 2002). "Key descriptors" for rural small farmers in Asia are: "deprivation, subsistence, illiteracy, survival and, because of globalization, vulnerability" (Devendra, 2007). Contrary to intensive large scaled production in China, which is reported to be greatly harmful to the environment (Steinfeld, 2006), the support of such smallholders would potentially provide large amounts of meat produced in an environmentally safe way. Furthermore, supporting China's poor rural farmers through livestock development is a direct contribution to the first millennium development goal (to eradicate hunger and poverty; Johnson, 2009), an abatement to China's serious challenge of rural-to-urban migration (Chen, 2007) and a means to reduce the income gap between rural and urban citizens (Sicular et al., 2007). An increased output from smallholders would also help the country in sustainably satisfying its steadily growing demand for meat (Thomas et al., 2002). "The development of small farms in Asian rainfed environments is a priority of the future and affirmative action is imperative" (Devendra, 2007). While we previously have analyzed major characteristics of pig keeping in mixed crop-livestock production systems in Xishuangbanna, Yunnan Province (Riedel et al., 2012), this paper examines the actual and potential productivity of those systems by using PRY Herd Life Model (Baptist, 1992a). Considering actual breeding and feeding strategies, reproductive performance, morbidity and mortality data as well as LW development, production efficiency in terms of saleable LW output per unit of feed input were calculated and evaluated in monetary terms, so as to identify promising areas of intervention for improving the productivity of pig units.

Materials and Methods

Area description

The study was conducted among smallholder pig farmers in southern Yunnan, the utmost southwestern Province of China. Households were located in the Naban River National Nature Reserve (NRNNR) in Xishuangbanna Prefecture (some authors refer to NRNNR as NRWNNR Naban River Watershed National Nature Reserve; Langenberger, 2011). The reserve covers altitudes between 450 - 2400 m a.s.l.; uncultivated areas are covered by tropical rainforest. Monsoon-dominated climate (avg. annual temp. 24°C and 2600 mm of rain between May and August) prevails in the lowlands while the highlands are slightly cooler and dryer. A previous study (Riedel et al., 2012) identified three main production systems: 1) Rubber (*Hevea brasiliensis* Müll. Arg.) based (RB) lowland (400-800 m a.s.l.) farmers in proximity to the major town Jinghong primarily cultivate rubber trees and fatten 2 - 4 purchased pigs with purchased fodder. Pigs in those systems only play a minor role for household (HH) income and rather serve diverse cultural purposes. 2) Pig based (PB) farmers (800-1200 m a.s.l.) manage slightly smaller rubber plantations with low production and additionally breed pigs (1.2 sows per HH), partially relying on self-produced and collected fodder. 3) Livestock-corn based (LB) farmers, located further from town at high altitude ranges (>1200 m a.s.l.) earn little income from tea plantations, cultivate rice and breed buffaloes and pigs (1.0 sows per HH).

Production systems

Only PB and LB farms were analyzed in this study, since RB farms only fatten pigs that are purchased elsewhere. Pig production on LB and PB farms is characterized by low monetary and high labor input. Animals are penned almost throughout the whole year but experience 1-3 months of free scavenging after rice harvest in October; fodder for the pigs is collected about twice a week on fields and in the forest and undergoes a time-intensive preparation of cutting and cooking. Mainly banana pseudo stem, crushed maize grain and rice bran are fed, few farmers (19%) additionally provide their pigs with small amounts of commercial feed such as fishmeal. While such rations do provide a decent amount of energy, they are deficient in protein (Rodríguez and Preston, 1997; Baihaqi et al., 2011), and therefore pig growth and performance are low. Very few farmers apply controlled breeding schemes while artificial insemination is neither applied nor known. Mating most often occurs randomly during the sows' free scavenging time, sometimes with wild boars from the forest (Riedel et al., 2012). A previous study on the pigs' reproductive performance under local conditions revealed a very high variation in performance between and within different production systems (Riedel et al., 2010). Commercialization of pigs is low, 25% (PB) and 20% (LB) of pigs are traded, mostly through casual farm-gate sales to middlemen. The so-called Small Ear Pig (SMEP), a small-framed and black animal with a concave back and slim, long nose which is also referred to as “Winter Melon Pig”, is the only breed in the analyzed systems. It is well known and preferred as local specialty among Jinghong citizens (Qian, 2009), but its effective marketing is hampered by high meat prices compared to pork from modern pig breeds raised in industrialized farms 200 km away near Simao City. Apart from two mentions - a “South Yunnan Short Eared Pig” is listed as southern Chinese pig breed in DAGRIS (DAGRIS, 2007), and a “South Yunnan Small Ear Pig” was mentioned by Cheng (1984) - the breed is rather unknown beyond the borders of Yunnan province, but animals with similar phenotypic characteristics are referred to in reports from nearby Laos and Vietnam and are named “Moo Lath” (Laos; Phengsavanh, 2010) and “Ban Pig” (Vietnam; Lemke et al., 2006).

Data collection and analysis

Reproductive performance data from 162 households, comprising 184 sows and 437 farrows, were collected using a progeny history questionnaire (Swift, 1981). The method aims at recalling the reproductive history of a female animal from birth up to the actual date by applying a structured questionnaire to its owner. Chronologically all events in an animal’s life are recalled and temporally linked to a known specific event in the past (seasons, festivals and widely known national or international events) to recover the date when the animal-related event happened. Since no example for the application of a progeny history survey to pig farmers was found, questions were adopted from a survey developed for camel breeders in Kenya (Kaufmann, 1998). The obtained information was assorted into categories to calculate the following data: means and frequency distribution of first farrowing age, farrowing interval, litter size, piglet and pig survival rate, culling rate and culling age (Table 5).

Data on LW development were obtained through three-weekly weighing of 114 growing pigs from 21 HH during a 14-months period. Sows once recognized pregnant were excluded from weighing. For each group, male and female growth data were merged to create a normalized joint growth curve. For modeling purpose, typical distances between male and female growth and final weight were simulated by applying the factors 0.92 and 1.07 for female and male growth, respectively (the factors represent the median influence of sex on average final LW of 13 common pig breeds; own calculations). Growth was standardized for each animal by averaging daily weight gain (g) between day 200 and 600. Although farmers did not separate growers by performance, four grower groups

(G1–G4) were extracted from those standard growth rates by separating their normalized (logarithmic transformation) standard growth rates (average daily weight gain, ADG) into four categories: Bad performer (G1): ADG ≤ mean - standard deviation (SD); Normal performer (G2): ADG > mean – SD and ADG ≤ mean; Good performer (G3): ADG > mean and ADG ≤ mean + SD; Very good performer (G4): ADG > mean+SD. Growth curves were computed by the Richards nonlinear growth model (Fekedulegn et al., 1999) for each growth group as follows:

$$\omega = \frac{\alpha}{(1 + b * e^{(c*t)})^{\frac{1}{m}}}$$

Equation 1: Richards function for modeling pig growth

Where W = live weight (kg), t = age in days, b, c and m = parameters specific for the function and e = Euler's number. The formula fitted best the growth of smaller pig breeds in comparison to logistic, Gompertz, von Bertalanffy, and Brody growth algorithms (Brown et al., 1976; Kebrab et al., 2007; Köhn et al., 2007). SMEP-specific parameters for the Richards growth model were determined according to the approach outlined by Kahm et al., (2010). Species-related production parameters were collected through literature review and are specified in Table 5.

Composition and energy content of pig feed was determined during 14 months of data collection in 21 HH (10 LB and 11 PB). Participating farmers recorded quality and quantity of feed given to a fixed number of pigs on a daily basis. The typical ration composition (Table 6) was identified based on those observations, and the metabolizable energy (ME) concentration of the typical feed mix was calculated from literature values for corn and rice bran (DLG, 2010), own feed analyses and a digestibility trial for banana pseudo stem (Baihaqi et al., 2011). Large numbers of banana plants are growing in the forests and around settlements, but they require work force for harvesting, transporting and cutting. The monetary values of feed were determined as follows: Based on an average salary for an uneducated day-laborer (60 Chinese RMB; 10 RMB ~ 0.90 € during time of data collection), the opportunity cost of collecting and processing 30 kg of fresh matter (FM) banana pseudo stem was estimated at 15 RMB. Rice bran as well as corn are marketable goods, corn was priced 1.5 RMB per kg DM and rice bran 0.7 RMB per kg DM at local markets during surveying. Additional costs of pig production, such as housing, labor and firewood for feed preparation, were not considered. Sales prices of pigs showed slight seasonal variations (±5 RMB per kg), which were not considered, while price dynamics with respect to the age of the traded animal were considered. Departing from an average price (30 RMB kg^{-1} LW), female offspring at 4 months age (weaned) is priced 1.4 fold higher than the base price. Animals of both sexes then reach a common 1.2 fold price between 12 to 28 months (fattened), while the price for animals older than 40 months drops to 0.6 times the base price.

Table 5: Input parameters for PRY Life Herd Model and their sources

Parameter	Unit	Source	Formula/Values	Changed in Scenario II	Changed in Scenario I
Mortality, Male	% of population per month	Survey	see Results	x	
Mortality, Female	% of population per month	Survey	see Results	x	
Culling rate per parturition	% of population per parturition	Survey	see Results	x	
Age at first parturition	Months	Survey	10.1	x	
Parturition interval	Months	Survey	7.7	x	
Litter size	Piglets	Survey	5.8		
Feed energy content	MJ ME per kg of DM feed	survey	19	x	
Energy efficiency lactation	quotient	Noblet and Etienne, 1989	0.72		
Litter weight gain from milk	kg for total litter	own calculation	weight at average weaning age / 2	x	*no changes*
Milk energy content	MJ ME per kg	Noblet and Etienne, 1989	5/4.6 MJ ME		
Bodyweight metabolic exponent	quotient		0.75		
Energy efficiency gestation	quotient	Noblet and Etienne, 1987	0.48		
Price per kg LW	RMB	Survey	30 RMB ~ 2.70 €	x	
Age at maturity	months	Model specification	Age at first parturition x 2	x	
MJ per kg of liveweight gain	MJ ME	own calculation	8.80 - 18.97		
Maintenance requirement	MJ ME	Rodriguez-Estev, et al., 2010	0.34 * metabolic weight		
Energetic efficiency coefficient	quotient	Webj, 1980	0.65		

DM = dry Matter; ME = Metabolic energy, RMB = Ren Min Bi (local currency)

Table 6: Ingredients and energy content of traditional pig feeds

Ingredient	Energy content of ingredient (MJ ME/ kg DM)	DM in FM of Ingredients	% per kg FM feedmix	% per kg DM feedmix	Contribution of energy (MJ ME) per kg feedmix
Banana pseudo stem	4.7	5%	58	8	0.38
Crushed maize grain	16.5	80%	34	75	12.42
Rice bran	10.4	80%	8	19	2.12
				Total feed energy (SQ+SC I)	14.92
				Improved feed energy (SC II)	19.39

DM = dry Matter; FM = fresh Matter; ME = Metabolic energy; Scenarios: SQ = Status Quo; SCI/II = Scenario I/II

The model

PRY Herd Life Model (Baptist, 1992b) was used to describe the pig population's current productivity and to test improved management scenarios. The model has been applied to a variety of systems and conditions as well as animal species: Goats in Oman (Dickhoefer et al., 2012), cattle in Niger, (dos Santos Neutzling et al., 2010), camels in Kenya (Kaufmann, 2005; Olukoye et al., 2005,), guinea pigs under laboratory conditions (Baptist, 1992a), and to various antelope species in Kenya (Fink and Baptist, 1992). Using the population-inherent fitness parameters, growth and reproductive performance, energy flow, produce value and culling strategy, PRY calculates herd productivity in terms of output per year (animal LW or monetary) and output per input ("total output value per unit dry matter intake") for different reproductive management and culling (sale and slaughter) strategies. An optimized culling strategy for highest feed efficiency in terms of lowest input per output unit can be displayed as well. While production-related input data are provided at herd level, all outputs are referring to one single female breeding animal. Male animals are not considered, assuming that they either are available in sufficient number or that artificial insemination is applied. No monetary determination of input parameters is required, however, production-related opportunity costs have been calculated. Further, return on investment (ROI) is presented in monetary and LW units. Figure 5 shows the procedure of data processing in a simplified manner.

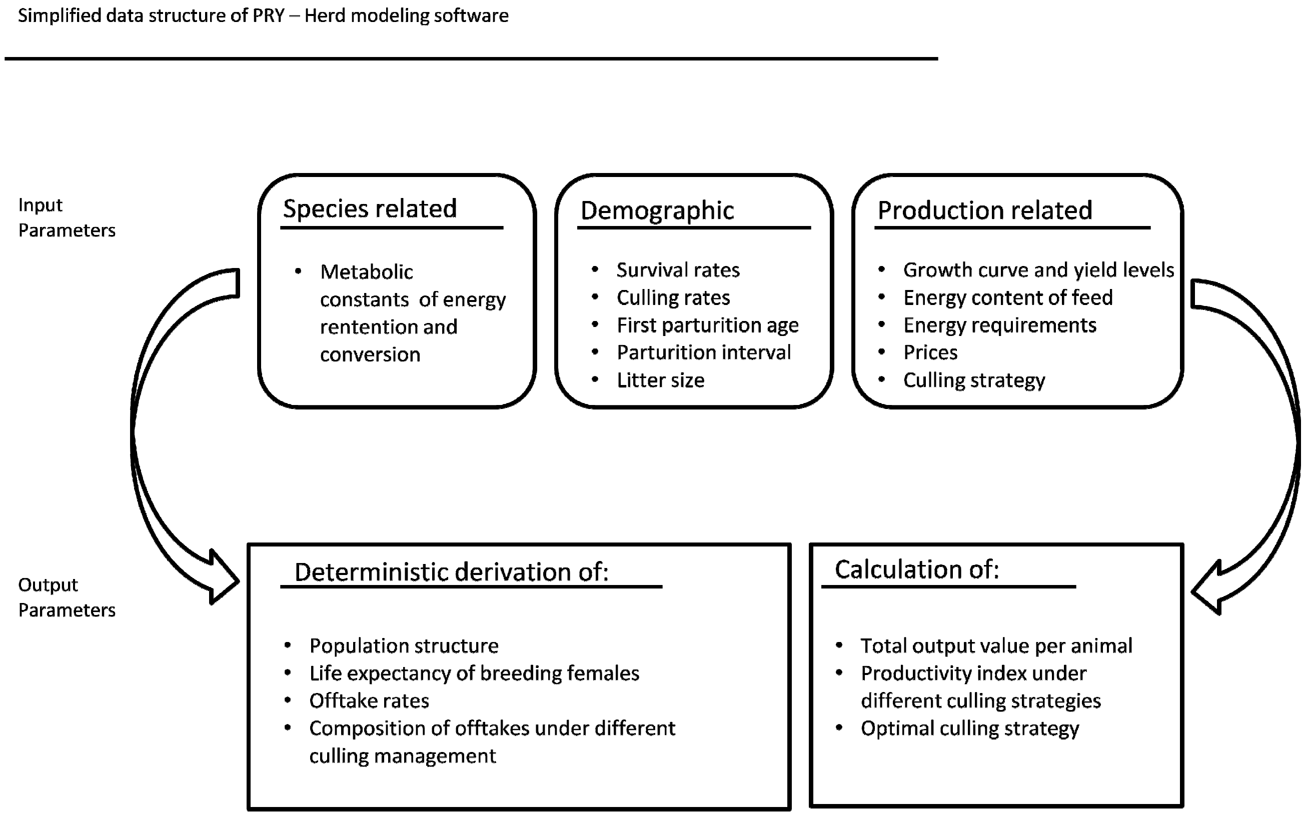

Figure 5: The structure of data-processing in PRY Life Herd Model

Data analysis

Mortality rates in the age-group 1-12 months were obtained from the progeny history survey and calculated separately for male and female animals on a monthly basis. Total mortality between 12 months and the maximum biological age of 10 years was set at 80%. Based on the progeny history information, classes of two months span were defined for age at first farrowing, with the minimum being 7 - 9 and the maximum being 23-25 months of age. Likewise, classes of one month span were defined for the farrowing interval, starting at 7 and ending at 17 months. For both parameters a normal distribution of cases was insinuated with the minimum, maximum and mean of the curves being identical to the values determined through the progeny history interviews. Litter size showed normal distribution and remained unaltered. Prices for fattened pigs as well as weaning age recorded in the surveys were also included in the model. No quantitative data on culling age of sterile and infertile sows could be obtained, but according to qualitative interviews with pig keeping households the threshold for deciding to cull a sow due to sterility or infertility is relatively high. It is normal to wait for a sow's first pregnancy for more than 18 months, mostly due to the inability of farmers to purchase replacement animals. Small litters and conception failures therefore are involuntarily accepted. For modeling purposes, the percentage of sows culled for sterility (i.e., culled before the first farrowing) and infertility (i.e., culled due to reproductive failure after successful first parturition) was each set at 5%. The cull-for-age threshold was set to the age of the oldest reproducing animal found in the population (80 months). According to Riedel et al., (2012), female breeding animals are usually taken out of production at an age of 60 months while surplus offspring is slaughtered at an age of 24 months or sold at an age of 12 months, resulting in a weighted average utilization age of 20 months.

Modeled management scenarios

A first scenario, Status Quo (*SQ*), describes the actual overall herd productivity; it was modeled for the overall average pig herd, using average growth and reproduction data of the entire population. Scenario I (*SC I*) only differed from *SQ* in the culling management which maximized output (monetary) per kilogram feed DM input. The second scenario (*SC II*) simulated improved feeding management that lead to younger age at first parturition, shorter farrowing interval, lower pre-weaning mortality and faster growth. For this it was assumed that ME concentration per kg feed DM increased from 14.7 MJ ME to 19.1 MJ ME, and that the hygienic conditions of feeding and housing improved substantially. Together, these measures were assumed to result in a 30% improvement of each of the above mentioned reproductive parameters. Litter size is not strongly related to a sow's nutritional status (Cerisuelo et al., 2006; Hong, 2006), and therefore remained at *SQ* level. *SC II* additionally suggested direct marketing of pigs which - in contrast to the *SQ* and *SC I* sales practices to middlemen - resulted in 30% higher returns to farmers (Riedel et al., 2012) beyond the age-depended dynamic pricing.

Results

Growth performance

Average LW of non-pregnant pigs (n=114) was 10.5 kg (SD 4.34) at the age of 200 days and 32.6 kg (SD 7.90) 400 days later. Sex did not influence LW at day 200 (male: 10.6 (SD 3.87) *versus* female: 10.5 (SD 4.79); p>0.1) but had a significant impact on LW at day 600 (male: 34.2 (SD 8.58) *versus* female: 30.7 (SD 6.76); p<0.01). Average daily gain (ADG) for the whole population during that time span was 55 g d^{-1} (SD 59.6), with no differences between sexes and farm types (p>0.1), but with differences between litters and owners (p<0.01). An ADG of 24 g d^{-1} (SD 3.8), 18 g d^{-1} (SD 3.1), and 28 g d^{-1} (SD 4.2), respectively, was observed across all (n=15), male (n=7) and female (n=8) pigs of G1. Since only very few G1 pigs were fattened beyond an age of 450 days, ADG values for group G1 only reflect LW changes between 200 and 450 days of age. ADG of groups G2, G3 and G4 (Table 7) amounted to 45 g d^{-1} (SD 11.8, n=42), 59 g d^{-1} (SD 27.9, n=43) and 141 g d^{-1} (SD 37.8, n=14).

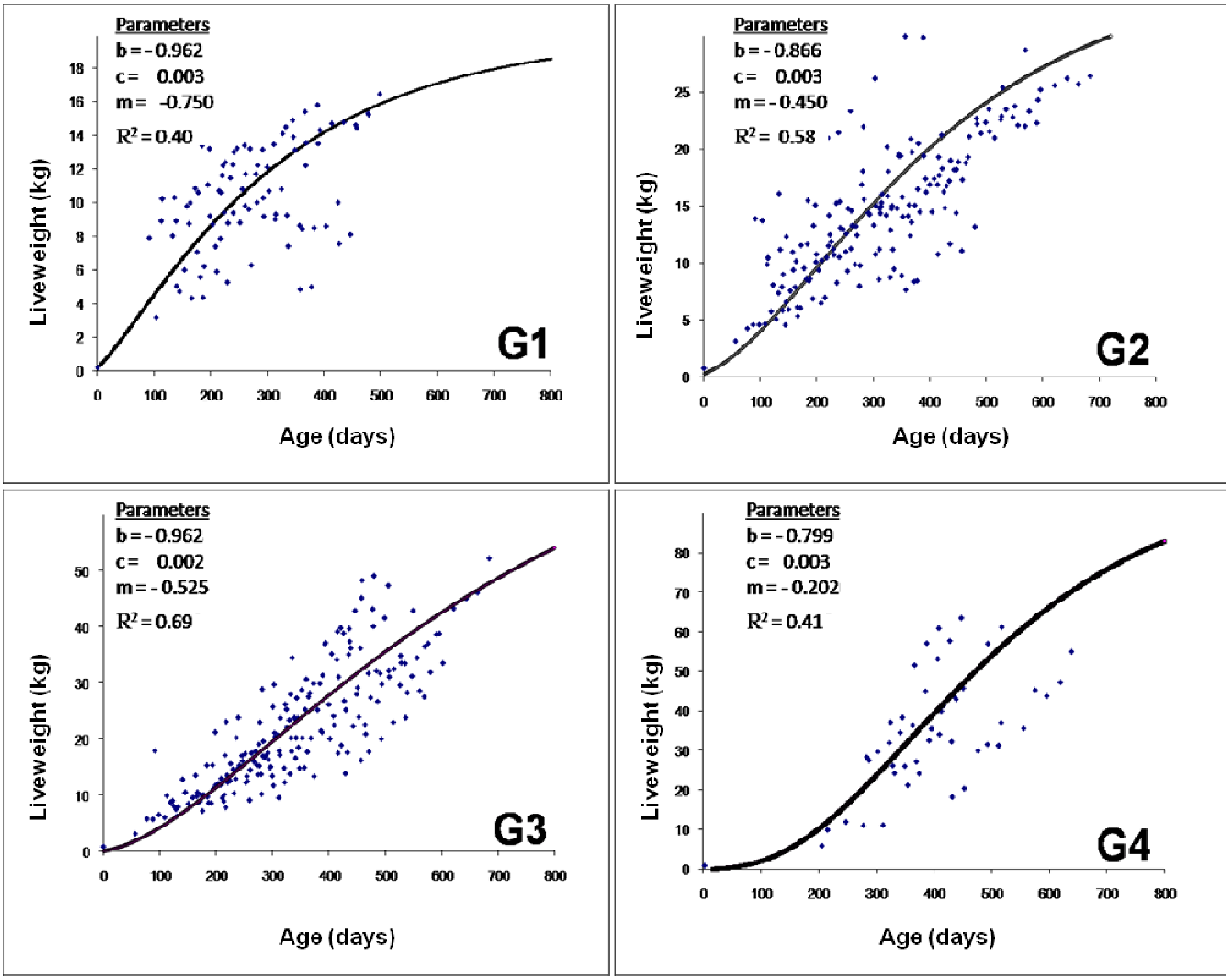

Figure 6: Age-weight relations of four different grower groups (G1-G4) and growth curve modeled according to Richards function [Eq. 1]. G1: bad performers, G2: normal performers, G3: good performers, G4: very good performers. For details see Materials and Methods section

Table 7: Average daily weight gain (ADG); g per day) and life weight (LW; kg) of fattening pigs aged between 200 and 600 days

		Total population			Male pigs			Female pigs		
		Mean	SD	#	Mean	SD	#	Mean	SD	#
Whole population										
	ADW (g)	55.0	59.6		76			52.0		
	LW age 200d (kg)	10.5	4.34	299	10.6	3.87	146	10.5	4.79	153
	LW age 600d (kg)	32.6	7.90	64	34.2	8.58	30	30.7	6.76	27
G1[1]										
	ADW (g)	24.0	3.80		18	3.10		28.0	4.2	
n=15	LW age 200d (kg)	9.2	2.74	60	10.7	2.70	27	8.0	2.12	33
	LW age 450d (kg)	15.2	0.65	7	15.3	0.70	5	15.0	0.43	2
G2										
	ADW (g)	45.0	11.80		37	10.60		47.0	12.4	
n=43	LW age 200d (kg)	9.5	3.52	135	9.2	3.03	65	9.9	3.95	70
	LW age 600d (kg)	27.4	5.24	27	23.8	1.75	7	28.7	5.46	20
G3										
	ADW (g)	59.0	27.90		58	26.50		61.0	29.7	
n=43	LW age 200d (kg)	11.9	3.93	98	11.9	4.27	53	12.0	3.48	45
	LW age 600d (kg)	35.5	5.74	25	35.2	5.38	18	36.3	6.5	7
G4										
	ADW (g)	141.0	37.80		194	35.30		207.0	39.1	
n=14	LW age 200d (kg)	22.5	10.94	6	25	0.0	1	22.0	11.92	5
	LW age 600d (kg)	78.8	6.23	5	78.8	6.23	5	n/a	n/a	0

[1] G1 performers were slaughtered before day 600, consequently day 450 was listed as final weight, n = number of pigs weighted, # = number of individual weightings

Reproductive performance

Age at first farrowing averaged 14.5 months (SD 4.34). While few animals had their first offspring at an age of 8 months, others only gave birth when older than 2 years. The time span between subsequent litters was 11.4 months (SD 2.73), ranging from 7 to 16 months. An average litter comprised of 5.8 (SD 1.94) piglets (median=4, range 1 - 11, n=158 litters). Piglets were not actively weaned but stayed with the sows as long as they desired, resulting in 4.3 months (SD 0.99) weaning age (range: 2 – 7 months). According to our survey data, abortions or piglets born dead accounted for 0.3% of all born piglets, but higher numbers are probable due to eventual deliveries outside of pens; 18% of all piglets born alive died before weaning, 2% more in the months between weaning and the age of 12 months, resulting in an overall mortality rate of 20% within the first year. Of pigs older than 12 months, 2% were lost per year. While losses within the first year of life only comprised deaths, losses of pigs older than one year also comprised stolen and run-away pigs ("disappeared"). Of the surviving fattening animals, 24.3% were self-consumed, 12.4% were gifted and 20.7% were sold. All other pigs covered by the progeny history survey (n=41 for PB, n=79 for LB) still were present at the farms during the time of interview. The average off-take age for young stock was 261 days (SD 139.2) with self-consumed pigs slaughtered at an age of 321 days (SD 124.3), and off-takes through gifting or selling occurring at an age of 227 days (SD 136.4).

Actual herd structure

Each pig breeder kept an average of 1.2 sows plus offspring. Most males were castrated after birth, and two to four breeding boars were found per village. The average age of breeding females (i.e., females that had at least had one litter before the interview) was 40.7 months (SD 14.01, n=73), the youngest one being 13 months and the oldest 80 months old. The age of breeding sows was normally distributed (Kolmogorov-Smirnov test, p=0.20).

An average pig breeding unit on PB and LB farms consisted of 16% breeding females and 84% fattening offspring, equivalent to 1.2 sows and 6.3 fattening pigs per farm. Life-time production of a sow was 2.6 litters in a 3.4 years life span. A female was replaced after 2.4 years of life (generation interval), 54% of all existing females were fattened while the remaining 46% were future breeding animals or died unutilized.

Productivity under different management

Under current management (*SQ*), where sows are disposed at an age of 60 months and fattening piglets are utilized at an average age of 20 months, a single sow produces an average utilizable output of 12.7 kg LW per year, which comprises culled male and female fattened pigs as well as disposed female breeding animals, with an equivalent monetary value of 391 RMB. Each year, 176 kg DM of feed of the above stated quality is required for that production, resulting in 0.07 kg of salable LW produced per kg DM offered (Table 8).

The input-output ratio of the modeled average pig unit was improved in *SC I* which aimed at maximizing input factor efficiency in terms of kg produced LW per kg feed DM offered. To achieve this, female breeding animals would have to be slaughtered at an age of 21 months and male and female fatteners at 7 months of age. Under these conditions one sow produces 16.7 kg of saleable LW output per year, 1.32 times more than under *SQ*, and yields a 1.47-times higher monetary output (573 RMB). At the same time feed requirements decrease to 140 kg DM feed per year, or 80% of the current feed input. The average saleable LW output per year comprises of 11.9 kg from fattening animals and 4.8 kg from disposed breeding females. Overall saleable LW production per kg of feed DM input amounts to 0.13 kg, an increase of 72.6% in comparison to *SQ* (Table 8).

Table 8: Productivity of NRNNR pigs under different management scenarios

	Cull age		**Input per year**	**Output per year**		**Input-output-ratio**	
Parameter	Breeding sows	Fatteners	Feed	Monetary	Live weight	Monetary	Saleable live weight
Management	*(months)*	*(months)*	*(kg DM)*	*(RMB)*	*(kg live animal)*	*(RMB / kg feed DM input)*	*(kg / kg feed DM input)*
SQ	65	20	176	391.2	12.7	2.3	0.073
SC I	21	7	140.4	573.3	16.7	4.1	0.126
SC II	20	7	123.2	1033	23.2	8.4	0.196

SQ = Status Quo; SCI/II = Scenario I/II; DM = dry Matter; RMB = RenMinBi (1 RMB ~ 0.80 Eur)

Simulating optimized management as defined under *SC II* for a standard pig unit yields an average annual LW output of 23.2 kg worth 1033 RMB, with a feed input of 123 kg DM, resulting thus in a production of 0.196 kg LW per kg feed DM and an overall productivity increase of 269% compared to *SQ*.

If pig litters were split into the four growth performance groups (Table 9), G1 pigs produced a higher yearly salable LW output (16.7 kg) under *SC II* compared to the total average yields under *SQ* conditions (12.7 kg LW), and had a lower feed requirement (89 kg DM year^{-1} under SC II *versus* 176 kg DM year^{-1} under *SQ*).

Under *SC II*, pigs with G2 growth characteristics would require 123.0 kg feed DM per year to produce an annual output of 23.2 kg LW, resulting in an overall productivity of 0.20 kg LW per kg feed DM. Productivity (0.32 kg LW kg^{-1} feed DM) as well as annual saleable output (31.2 kg LW) was slightly higher for G3 than for G2 pigs and was highest for G4 pigs. With a feed input of 260 kg DM per year, an average output of 62.9 kg salable LW (0.24 kg LW kg^{-1} feed DM) worth 2706 RMB could be gained (Table 9).

Table 9: Productivity of performance sub-groups under improved management (SQ II)

	Cull age		**Input per year**	**Output per year**		**Input-output-ratio**	
Parameter	Sows *(months)*	Fatteners *(months)*	Feed input *(kg DM)*	Monetary output *(RMB)*	Live weight output *(kg live animal)*	Monetary *(RMB / kg feed DM input)*	Saleable live weight *(kg / kg feed DM input)*
Performance Group							
G1	20	7	88.7	718	16.7	8.09	0.19
G2			114.5	1015	23.2	8.87	0.20
G3			149.6	1334	31.2	8.91	0.21
G4			260.5	2706	62.9	10.39	0.24

Comparing only the cost of feedstuffs with the monetary value of the saleable LW outputs current production practices (*SQ*) have a negative monetary return on investment (Table 10). With an annual LW production worth 391 RMB and feed expenses of 580 RMB, each RMB invested returns only 0.67 RMB. If farmers would sell all marketable feedstuff (corn and rice bran) instead of utilizing it in pig production, their income exceeded the value of produced pig LW by factor 1.71. Under *SC I*, each RMB invested would already return 1.24 RMB, a 3.15 times higher ROI than what could be gained if marketable feedstuffs were directly sold. Under *SC II* all grower groups yielded a positive

ROI (2.45, 2.69, 2.70 and 3.15 RMB per RMB invested for G1, G2, G3 and G4) if feed prices remained at *SQ* level.

Table 10: Comparison of Return on Investment (ROI) between different grower and management groups of pigs in NRNNR, Yunnan, Southern China

		PER UNIT (breeding sow plus offspring) and year								
Management	**Unit**	**DM feed input**	**Amount BPS (FM)[1]**	**Amount CMG (FM)[1]**	**Amount RIB (FM)[1]**	**Cost of feed[2]**	**Opportunity cost of marketable feedstuff**	**Value of saleable live weight produced**	**ROI pig produ-ction**	**Difference in income from pig production vs. selling marketable feedstuff**
		(kg)	*(kg)*	*(kg)*	*(kg)*	*(RMB)*	*(RMB)*	*(RMB)*	*(Ratio)*	*(Ratio)*
SQ	total population	176.0	704	132	44	581	229	391	0.67	1.71
SC I	total population	140.0	560	105	35	462	182	573	1.24	3.15
SC II	G1	88.7	355	67	22	293	115	718	2.45	6.22
	G2	114.5	458	86	29	378	149	1015	2.69	6.82
	G3	149.6	598	112	37	494	194	1334	2.70	6.86
	G4	260.5	1,042	195	65	860	339	2706	3.15	7.99

Only direct feed prices are considered, higher prices for energy optimized SC II feeding is not included

[1] Amount of FM required annually, BSP= Banana pseudo stem; CMG = crushed maize grain; RIB = Rice Bran

[2] Expenses only cover price of feed and do not include any time invested in pig production.

Prices: Maize grain (kg FM): 1.5 RMB; Rice bran (kg FM): 0.7 RMB; Banana pseudo stem (30 kg FM): 15 RMB; SQ = Status Quo; SC I/II = Scenario I/II; G1-G4 = Growth Groups (See Figure 6); FM = fresh Matter; RMB = RenMinBi (1 RMB ~ 0.80 Eur); vs. = versus

Discussion

Model performance and data quality

The PRY Herd Life Model (Baptist, 1992b) has been designed for species-independent applications, and in fact has been applied to a wide range of livestock species in the past, but to our knowledge has not yet been applied to pig systems. However, since all species-related input parameters are modifiable, the application to a new species is relatively easy, as long as all parameters are available (Table 5). For pigs being a well-researched species, all necessary data were available from publications, sometimes at species level (e.g., milk energy content, milk energy conversion rate into piglet weight gain). In other cases experiments from extensive tropical rearing systems provided data of sufficient precision. The technical aspects of parameterizing PRY for use with pig herds were therefore successfully mastered.

Given the model's reliance on herd and year-based average values, a determination of farms' individual management and seasonal fluctuations is not possible. Strong variations between different farms and seasons therefore rather blur the results instead of providing higher accuracy. As an example, our dataset featured large variations in first farrowing age as well as inter-farrowing interval. Model results however are only valid as average result for the areas' overall pig herd but a characterization of individual performances at different farms could not be provided. Hary (2000) has recognized and discussed that constraint of PRY and other commonly used herd models. He acknowledges the limitations of such models but at the same time highlights that enormous amounts of data need to be processed in a complex manner to gain individual results with farm- and season-specific resolution. Such calculations, however, would be very useful in analyzing resource-driven production systems. Bottlenecks in nutrient supply during off-seasons might reach a critical limit and by that could heavily influence the overall annual production. On the other hand, observations suggest that nutrient content of feed during post-harvest seasons sometimes is higher than the actual requirements of animals (Peters et al., 2005). While average annual figures provide valuable data for the general evaluation of the performance of pig farms, the seasonal availability of feed is a core bottleneck for production and an extension of PRY with a module handling this seasonality would greatly improve its functionality.

Another major constraint in modeling pig herds with PRY is the fact that feed-related calculations are solely based on feed energy intake and retention. Although, for the feed-related modeling-part, return on invested feedstuffs (DM) can be optimized, the specific protein and essential amino-acid requirements of monogastric animals is at present not dealt with by the model, and would need to be integrated. This shortcoming does however not affect the usefulness of the model as a tool for comparing the management of different groups of animals within a given setting, and virtual testing of new management options that might improve herd productivity within that same setting (Kaufmann, 2005; Dickhoefer et al., 2012). More precise parameterization of feed requirements and determination of the optimal culling age, however, would require further controlled experiments on aspects such as lean meat and fat accretion in relation to the animals' growth performance and age, and a more precise estimation of energy losses through unhygienic conditions and outdoor locomotion, which can require almost half of the digested energy in extensive systems (Rodriguez-Estevez et al., 2010).

Despite these limitations, we are confident that the simulated results are realistic; the feed DM requirements which have been calculated by PRY for *SQ* were similar to those that farmers recorded as actual amounts of feed given to pigs in the one-year feed-recording survey (see Materials and Methods).

Progeny history surveying served as data source for the system-specific reproductive parameters and mortalities. This methodology has been applied successfully in different studies with ruminants, but has not yet been published for pig studies. A crucial point for obtaining appropriate data quality is the ability of farmers to remember past reproductive events of their female stock. Cattle farmers of the Sahelian zone, for example, highly value their animals and have precise remembrance about their histories. Single births, long life spans and a special care of herders for their animals, make it easy to remember the history of individual females. Under such conditions, Kaufmann (2005) was able to recite 15 years of reproductive history in camels from north Kenyan herders. Interviewing a small number of farmers in such cases can already provide a notable amount of data covering a longer time frame. Progeny history surveying in pigs is different. Animals have shorter reproductive intervals and life spans, litters are large and farmers have less personal connection to the individual animal. Tracing a sow's history back for more than three litters to remember reproductive details takes a long time and most farmers could not provide precise data beyond the last three litters. Consequently, a large number of survey participants was required to obtain reliable data for concise modeling. The data then represented only a time span of a few years and the impact of recent area-wide events, such as climatic fluctuations or epidemics, can have a significant impact on the results. Further, the influence of different management systems within the analyzed population can increase variance in the data. Although a strength of the PRY model is its capability to handle data from very diverse systems and species, its requirement for a large diversity of input factors increases the risk of erroneous estimations. In the current case, however, we are confident that the progeny history approach provided sufficiently accurate data for the evaluation of the actual productivity of pig systems in the NRNNR and of potential measures for improvement, since our model results (*SQ*) were confirmed through the practices and views of smallholder farmers and managers of larger-scale commercial farms in the study area.

Growth performance of pigs

The growth curves developed for this study were showing relatively low regression coefficients (R^2) (Figure 6, however, the recorded data showed a very high variation. For example, LW at 600 days of age in the total population ranged from 21.5 kg to 64.1 kg, but for each of the four grower groups, LW at 600 days of age had reasonable low SD values of 5.24 (G2), 5.74 (G3) and 6.24 (G4). Most growth curves for pigs are based on relative homogenous populations (e.g. Koehn et al., 2007), only few studies calculated growth curves for heterogeneous pig populations. With respect to the latter, Kebrab et al., (2007) suggested to handle final LW as random effect and thus generate a common Richards growth curve for pigs such as SMEP with strongly different daily gain and final LW.

The above discussed variation in growth occurred despite the fact that all pigs had similar outer appearance (except of body size) and were identified as one common breed by the local owners. No clear reason for this divergence could be identified, since the variation occurred seemingly random in pig families, individual farms and farming systems, with none of those factors separating growth performance into significantly different groups. Very different final weights, however, are a strong sign for large genetic variation, which may have the highest impact on different growth performances, especially since a first evaluation of feeding practices (unpublished data) did not reveal strong variation in feed quality between farms. A study from Vietnam (Lemke et al., 2006), observed 136 and 177 g d^{-1} of LW gain in semi-intensive production systems near town and 66 and 85 g d^{-1} in two traditional systems where feeding was based on resource availability rather than on the pigs' requirements. With the exception of G4 growers, growth rates of NRNNR pigs (24, 45 and 59 g d^{-1}) were in the range of those traditional Vietnamese systems, which were based on a local pig breed (Ban breed) as well (Lemke et al., 2006). G4 growers, however, showed performances similar to crossbred pigs in more intensive systems (Lemke et al., 2006). The potential daily gain of local breeds in well-managed SE Asian systems can be as high as 230 g in the LW span of 35 to 65 kg (Falvey, 1981). The suspected high genetic variation within the analyzed pig population might thus indicate that breeding programs bear a high potential for improving pig production, while the current breeding 'approaches' do not have a noticeable impact on the average performance of the total population.

Feeding management

PRY does not account for the energy required per kg LW gain and day, but is averaging ME requirements of the total breeding unit (female plus offspring) and therein includes energy lost in died offspring; the average energy requirement per day and breeding unit was therefore set at 0.54 MJ ME (ADG = 55 g d^{-1}). A large proportion of that requirement was spent on the maintenance energy requirement of the sow during long unproductive periods, while another important share of available ME might have been utilized inefficiently in the long suckling periods. In comparison, Kirchgeßner (1997) suggested a daily requirement of 0.4 – 0.5 MJ ME d^{-1} kg^{-1} LW of fatteners weighing 30 - 60 kg and growing at 500 g d^{-1} for improved pigs under optimized controlled conditions. Sows of undefined LW in smallholder systems (Vietnam) received 31.9 ± 20.1 MJ ME d^{-1} varying between seasons, locations and reproductive states; of those, the ones on farms "far away from town" received 20 - 30 MJ ME day^{-1} (Lemke et al., 2006). Assuming that the average LW of such sows was 50 - 70 kg, these feeding regimes would offer 0.28 – 0.6 MJ ME d^{-1} kg^{-1}. Tra (2003) calculated an offer of 5 – 40 MJ ME day^{-1} per sow in similar Vietnamese smallholder systems. Both studies reported high seasonal fluctuations in feed supply and suggested that feeding is strongly determined by the availability of feed rather than accounting for the pigs' actual feed requirements. This is a common finding for smallholder systems where regular income generation is not the primary target of production (Bennison et al., 1997; Nakai, 2008). While feed availability in general is a constraint to production, malnutrition during off-seasons is an often cited core bottleneck in Asian pig production systems. Among nine recommendations for improvement of such systems, Devendra and Leng (2011) identified the "development of year-round feed systems" as core part of a strategy for sustainable enhancement of Asia's smallholder livestock sector.

By testing the two improved management strategies *SC I* and *SC II*, we explored another option to efficiently utilize available feed sources. Compared to *SQ* management, the overall feed use efficiency (= feed ME or DM, respectively, required per unit of output) has been improved under *SC I* and *SC II* management. The improvement mainly arose from the shortening of unproductive periods in the life of sows, which constantly require energy for maintenance, but also through the utilization of fatteners before maintenance energy requirements account for a larger share of overall energy requirements due to reduced ADG in older animals. Combining the various aspects which include a better seasonal balancing of annual feed supply, the synchronization of reproductive stages with feed seasonality and an optimized culling strategy, pork production of the analyzed and similar smallholder farms could experience large improvements.

Reproductive performance

Sows of native breeds under traditional management in other Asian countries were often reported to have higher litter sizes than what we recorded (Philippines: 8.5 (Lanada et al., 1999); Thailand: 7.1 (Nakai, 2008a); Laos: 6-8 (Stuer et al., 2002)). Measures to increase litter size (and also to reduce early mortality), however, are not of major importance for fattening systems, as long as the observed nutritive deficits are not solved. Yet, if a breeder turned into a seller of weaned piglets, litter size would be a core productivity parameter, and measures to increase the number of weaned piglets would strongly be welcomed. A study from Thailand indicated that high temperature and humidity have negative effects on litter size of crossbred sows (Suriyasomboon et al., 2006). Pre-weaning mortality (10% in male, 13% in female pigs) in the NRNNR was in an acceptable range, similar or even poorer results were reported from comparable studies in Vietnam (12 - 33%, Lemke et al., 2006; 4%, Thuy, 2001), Thailand (16%; Nakai, 2008) and the Philippines (13 - 19%, Lanada et al., 2001). Often, crushing is an important reason for pre-weaning losses in pens without piglet refuge section (Edwards et al., 1994) which can easily be prevented through proper housing. The evenness of male and female piglet mortality indicates that castration was done properly and not leading to infections.

Average weaning periods of four months are very long. No comparative data were found from similar Asian systems, but early weaning is common practice in intensive production systems, since sows experience heavy nutrient turnover during suckling periods and in the absence of proper feeding this can easily lead to nutritional deficits (Thaker and Bilkei, 2005). Although prolonged suckling is temporarily leading to quicker piglet growth, in the long term this practice emaciates the sows. Inter-farrowing intervals are delayed (Tantasubaruk et al., 2001; Thaker and Bilkei, 2005) and the sow lacks the ability to adequately nourish the piglets of the next litter. We suspect long inter-farrowing intervals as well as old age at first gestation to be caused by the (seasonal) malnourishment of the sows in NRNNR. While growing pigs can easily compensate periods of under-nutrition once they are fed properly again, the sow's productivity is heavily affected by such periods (Kirchgeßner, 1997). In the absence of sufficient and adequate feed resources in terms of both energy and protein content, the traditional smallholder farmers in the NRNNR should therefore pay special attention to the nutrition of their sows. A possible option could be to synchronize reproductive cycles with the seasonal availability of higher quality feedstuffs. Under the current management, with less than one litter per year, the farrowing period should occur during post-harvest time, when nutrient-rich green plants and crop leftovers are available in larger amounts. Seasonal timing of farrowing, however, actually is not a common practice among SE Asian smallholder pig producers (Lemke et al., 2006; Nakai, 2008a). Splitting feed into portions with better and lower quality to be respectively provided to sows and fatteners could additionally help to face the nutrient challenge for sows in productive stages. This management is common in intensive production systems and sporadically found under tropical smallholder conditions (Peters et al., 2005; Lemke et al., 2006).

Culling and marketing of pigs

With the adoption of an improved culling management alone, the model calculated a 72% improvement in productivity and a 31% increase of salable LW outputs. This approach would also save valuable labor time because less feed would be needed (reducing collection and preparation time). In addition, it would improve the utilization of naturally available or farm-grown feed resources and help farmers to gain an overall better price for their products. In reality, however, improved culling and feeding schemes are only sustainable if trading of products can occur at any moment. Data from a former study (Riedel et al., 2012) showed that presently this is not the case and sales rather occur occasionally when mobile unannounced traders visit the pig farms. The result of such a random marketing scheme is the very high variation in the age of sold animals. Self-consumed pigs were slaughtered at an even older age, leading to the conclusion that pigs are kept on hold for eventually occurring sales and only are self-consumed if sales options do not materialize. In consequence, the management improvements simulated under *SQ II* only are applicable if respective marketing opportunities are created. Such implications should ideally be supported through local institutions, and involve the pig farmers' community (Devendra, 2002).

Conclusions

A first application of PRY Herd Life Model to simulate pig herds' productivity under actual and assumed improved management (scenarios) was successful, although the model only provides year- and herd- average data, while quantifying seasonal fluctuations would contribute greatly to the identification of sustainable management practices. The comparison of model results with data that has been collected in our surveys and with results reported for the region demonstrates that the calculated results are realistic. Although pigs' protein requirements could not be taken into account by the model, the productivity calculations based on the diets' ME concentrations allowed identifying some weaknesses of the current production system and showed the potential impact of possible improvements. Since at present the traditional pork production has a negative ROI, improvements are needed quickly. Although a positive ROI can already be achieved through an optimized culling management, our *SC II* simulation showed that the system holds the potential for a significantly higher productivity. To realize this potential various management changes need to be introduced, such as feed quality improvement (energy and protein concentration), strategic feeding of sows and offspring, timely weaning of piglets, controlled mating and the creation of reliable marketing channels that are coordinating farms' culling strategies. These measures would contribute to a more efficient utilization of available feed resources, increase farm output and economic return from pig production; their adoption would however necessitate a profound change of current management practices. Therefore farmers need to participate in the development of detailed management recommendations, so that cultural, seasonal and other not yet evaluated factors are properly accounted for and improvements can sustainably be adopted.

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Swamp buffalo keeping – an out-dated farming activity?

A case study on the importance of buffalo husbandry in smallholder farming systems in Xishuangbanna, Yunnan Province, PR China

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Abstract

Expansion of rubber tree plantations and agricultural mechanization provoke a decline of swamp buffalo numbers in the Naban River National Nature Reserve (NRNNR), Yunnan Province, China. We analyzed current use of buffaloes for field work and the recent development of the regional buffalo population, based on interviews with 184 farmers in 2007/2008 and discussions with 62 buffalo keepers in 2009. Three types of NRNNR farms were distinguished, differing mainly in altitude, area under rubber, and involvement in livestock husbandry. While pig based farms (PB; n=37) have abandoned buffalo keeping, 11% of the rubber based farms (RB; n=71) and 100% of the livestock-corn based farms (LB; n=76) kept buffaloes in 2008. Herd size was 2.5 ±1.80 (n=84) buffaloes in early 2008 and 2.2 ±1.69 (n=62) in 2009. Field work on own land was the main reason for keeping buffaloes (87.3%), but lending work buffaloes to neighbors (79.0%) was also important. Other purposes were transport of goods (16.1%), buffalo trade (11.3%) and meat consumption (6.4%). Buffalo care required 6.2 ±3.00 working hours daily, while annual working time of a buffalo was 294 ±216.6 hours. The area ploughed with buffaloes remained constant during the past 10 years despite an expansion of land cropped per farm. Although further replacement of buffaloes by tractors occurs rapidly, buffaloes still provide cheap work force and buffer risks on poorer NRNNR farms. Appropriate advice is needed for improved breeding management to increase the efficiency of buffalo husbandry and provide better opportunities for buffalo meat sale in the region.

Introduction

In 2009 an estimated number of 188 million buffaloes were kept worldwide, approximately 97% thereof in Asian countries. Besides the river type, which is dominant in South Asia, the swamp type accounts for 30% of the total population. Swamp buffaloes are mainly distributed in South East Asian countries (SEA), including southwestern China (FAO, 2012) (for simplified reading, South East Asia and southwestern China are referred to as SEA+C). While worldwide the total number of buffaloes increased by 12.5%, the swamp buffalo population decreased by 18.5% in SEA+C between 1990 and 2002 (FAO, 2012). Among others, possible reasons were agricultural mechanization, poor reproductive performance through bad management, and lack of proper attention by policy makers (Nanda and Nakao, 2003). In history, swamp buffaloes have been a central component of the regional crop-livestock systems by providing draught power, being able to work longer and pull heavier loads than any other draught animal available (Nanda and Nakao, 2003). Biological characteristics such as extraordinary heat tolerance (Nanda and Nakao, 2003), and their ability to move safely and pull heavy loads on muddy grounds made them a specialized "working tool" for rain fed and paddy rice systems under humid tropical conditions (Hibler, 2000). Being ruminants, buffaloes additionally are able to convert low quality feed from marginal land, which otherwise would remain unutilized, into high value protein (McDermott et al., 2010). Traditionally milk is not consumed much in SEA+C, but demand increases steadily through the adoption of new consumption patterns. China's overall milk consumption grew by 2.3% in 2003 (Kurup, 2004) and per capita consumption is projected to increase from 6 kg to 16 kg between 1993 and 2020 (Delgado et al., 1999, 2001). Similarly, meat consumption is expected to increase from 33 to 71 kg per capita (Delgado et al., 1999, 2001) in the same time span; this will not only will take place in urban centers but in rural areas as well (Joshi et al., 2007). Although pork will cover most of the demand for meat (Devendra, 2007), the demand for other types of meat is expected to grow as well, though to a lesser extent. Swamp buffaloes therefore mainly serve as draft animals and other use purposes remain of secondary importance. However, rural development advanced rapidly in many regions of SEA+C in the last decade, therefore the core utilization of the swamp buffalo is seriously challenged by the increasing use of small tractors and other machines for transport and draft power (Liang and Rahman, 1985; FAO, 2002). The global decrease in buffalo numbers, especially in countries with improved rural conditions, seems to prove that the services provided by buffaloes are not required anymore. Nonetheless, a majority of institutions and researchers still valuates them as a very important part of SEA+C smallholder agriculture. As an example, FAO labeled them "an asset undervalued" (FAO, 2000), and many strategy papers conclude with serious appeals to conserve and support buffalo keeping in such systems (Devendra, 2007; FAO, 2000, 2002; Nanda and Nakao, 2003). With shrinking buffalo numbers in a formerly buffalo-populated area in Xishuangbanna, Yunnan Province, in southwestern China, the target region of this study seems to follow the global trend: buffaloes have lost most of their former importance and may even totally vanish from this area in the near future. Based on two quantitative surveys and a set of group and key person interviews across three different farm types in the target region, this study aimed at understanding past development and current dynamics of the local population of swamp buffaloes, their present role for the farming systems and farmers' livelihoods, and their probable role in the near future.

Materials and methods

Study area

The study was conducted in the Naban River National Nature Reserve (NRNNR), which is located in Xishuangbanna prefecture, Yunnan Province, P.R. China. The prefecture is located in the utmost south Chinese mainland tip, bordered by Lao in the South and Myanmar in the West. The study area is characterized by mountainous topography with lowland plains at 500 m asl and peaks reaching as high as 2300 m asl. The tropical monsoon climate is characterized by two rainy seasons (one longer, May-October, and one shorter, February) and dry, cool winters. Annual average precipitation is 1630 mm, almost all rain falls in the longer rainy season. Overall annual average temperature is 21°C at lower altitudes but temperature drops at higher altitudes. Given its unique plant and wild animal diversity, the region was identified as one of the "major biodiversity hotspots in the world" (Myers et al., 2000). The NRNNR itself follows the UNESCO human-nature[5] concept, acknowledging man as part of nature and therefore allowing inhabitants to have moderate impact on their natural environment through settling and agricultural utilization. The area is inhabited by approximately 5500 people distributed across 24 villages. Five major ethnic groups (Han, Dai, Lahu, Hani and Bulang), each with unique language and culture, are found in NRNNR. Similarly to many rural areas in China, the study area underwent massive infrastructural improvement in the past few years, turning far off rural dwellers into city-connected parts of society. Quick economic growth and a significant change in agricultural land use through area-wide rubber (*Hevea brasiliensis L.*) cultivation, which started in the late 1960s, resulted in increasing incomes for farmers, but also lead to heavy deforestation and water contamination (Qiu, 2009). However, inhabitants of higher altitudes – traditionally with a large cultural and geographical distance to lowlanders – still are excluded from modernization of infrastructure, agriculture and lifestyles through language and topographic barriers.

Data collection and analysis

Two surveys were at the core of this study, and additional information was gained through field visits and a series of qualitative group interviews as well as individual interviews with selected farmers and other stakeholders in the region.

The first survey was conducted between January and May 2008. Questions to 208 farmers were targeting general aspects of agricultural activities in NRNNR, and aspects of land and livestock

[5] http://www.unesco.org/new/en/natural-sciences/environment/ecological- sciences/man-and-biosphere-programme/

utilization including buffalo herd sizes, and their reproductive, feeding and health management. In addition, socio-economic and cultural issues were tackled. A major outcome of this survey was the classification of the dominant farming systems in the NRNNR.

The second survey was conducted 12 months later, when 74% of the previously identified 84 buffalo keepers were interrogated again for further details on buffalo keeping. This survey aimed at understanding farmers' motivations to maintain or abandon buffalo husbandry, the integration of buffaloes in the farming setup, and the time management related to buffalo keeping and using them for labor. For an analysis of long-term developments, historical data on land use patterns (10 years ago) and buffalo sales prices (5 years ago) were collected as well.

In our data analysis, we present qualitative data to provide an overview on the general buffalo management and the perceptions of buffalo keepers. Quantitative data serve to capture the dynamics of buffalo keeping over time. For comparison of group means, quantitative data were subjected to non-parametric statistical tests (Kruskal-Wallis test and Man-Whitney-U test) using the software package SPSS (2010).

Results

Farming systems

Three major farming systems (Table 2) are prevalent in the study region (Riedel et al., 2012):

1) Rubber-based (RB; n=71) farms are mainly located at lower altitude ranges (800 - 1200 m asl), and are closest to town. 46.5% of RB farmers belong to the Dai minority, followed by Lahu (29.6%) and other ethnic groups. With increasing importance of rubber plantations that contribute the greatest share to RB farmers' livelihoods, they abandoned most alternative agricultural production, with small areas of staple crops and a few fattening pigs being the only other agricultural commodities left on RB farms. Only eight (11%) RB farms kept buffaloes in 2008.

2) Livestock-corn-based (LB; n=76) farms, mostly run by Lahu families, are located at higher altitude ranges (>1200 m asl) which are characterized by steep slopes and very small field sizes. LB farmers run traditional crop-livestock systems with rice, maize, tea, buffaloes and pigs building the core of their agricultural production. Buffaloes are regularly used as traction animals on all 76 LB farms.

3) Pig-based (PB; n=37) farms represent the interface between RB and LB farms. They are found at

all altitude ranges, have larger rubber plantations and tea fields and keep larger numbers of pigs than LB farms, but do not keep buffaloes.

The use of buffalo

Of the 184 farmers interviewed during the first survey, 84 kept buffaloes. Unless mentioned otherwise, data presented here is however based on information from 62 farmers only, who participated in both surveys. The reason to keep buffaloes was quite consistent among the 62 buffalo-keeping farmers: 87.3% were using them as draft source, for 79.0% additionally “lending buffaloes to neighbors or families in need” was another major motivation to keep this species. All respondents who stated to use buffaloes as working animals were using them for ploughing rice and corn fields, and most were using them for harrowing as well (66.1%). Transporting goods, such as timber or harvested crops, was a reason to keep buffaloes for only 16.1% of the buffalo keepers; 11.3% stated that trading buffaloes was a major reason for keeping them and 6.4% were keeping their animals for own consumption.

Buffalo herd sizes and herd composition in 2008 and 2009

In 2008, buffalo keeping households kept 2.5 ±1.80 (n=84) buffaloes with an average herd structure of 47% male and 53% female animals, 23% of them being younger than 2 years (Table 11). The majority (61.3%) of herds consisted of less than 3 animals, and the remaining herds comprised at maximum 6 buffaloes, except for one herd with 12 animals. In 2009 the average number of buffaloes per farm had dropped to 2.2 ±1.69 for all households included in the second survey (n=62), and to 2.5 ±1.58 for the 54 LB farms that still were keeping buffaloes in the end of 2009.

In 2009, 13.0% (17.8% LB and 8.3% RB farms) of the 62 interviewed buffalo keeping farmers had sold all their buffaloes. Among the LB farmers, 37.9% kept less buffaloes at the latter date, compared to the numbers in the first survey, while 48.3% had the same number of buffaloes and 13.8% were keeping more. Comparing the total number of buffaloes recorded in the two surveys, an overall decrease of 21.4% of the buffalo population was observed in the LB farming system. Similarly, but to a lesser extent, the buffalo population on RB farms was reduced by 9.5% in the course of 12 months. Additionally, two RB farmers stated that they would very soon abandon buffalo keeping and sell all their animals. Informal visits in 2011 confirmed the trend, 4 out of 6 visited farmers had sold all their buffaloes.

Table 11: Changes in buffalo numbers in buffalo keeping households (HH) between 2008 and 2009

Farming system	HH (n)	**Buffaloes** (n/HH) 2008		2009		Decrease of buffalo numbers	Decrease of herd size per HH
	2008 / 2009	Mean	SD	Mean	SD	%	%
Livestock-corn based	76 / 54	2.9	2.23	2.3	1.94	21.4	20.7
Rubber based	8 / 8	1.8	0.62	1.6	0.80	9.5	11.1
Total	84 / 62	2.5	1.80	2.2	1.69	14.6	12.0

Table 12: Working hours invested each day (h/d) by buffalo-keeping households to herd, guide and feed buffaloes

Activity		Herding in forest		Herding in mountains		Herding in crop fields		Guiding to grazing grounds		Forage cut and carry		Total hours per day	
Farming System	n	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Livestock-corn based	54	1.5	2.03	0.7	1.20	2.6	2.03	0.6	0.92	0.0	0.06	5.4	2.74
Rubber based	8	2.1	1.91	1.1	1.73	3.6	1.42	0.2	0.41	0.0	0.03	7.0	7.42

Table 13: Annual working time of a buffalo on different types of crop fields

		Working time (h/yr) in Rice fields		Corn fields		Hemp fields		Other crops		All plantations		Daily working time (h)	
Farming system	n	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Livestock-corn based	54	121.4	130.70	98.3	56.70	119.3	80.30	11.0	40.70	349.9	200.10	1.0	0.50
Rubber based	8	37.3	35.50	55.0	65.90	-	-	-	-	92.3	77.70	0.3	0.20

Recent changes in land use patterns

The general dynamics of the area cultivated per farm and the developments regarding the area cropped with the five dominant crops are depicted in Table 14. From 1999 to 2009, the total area of cropland per farm increased significantly ($p<0.05$) from 1.5 ha to 3.2 ha (+113%) on buffalo-keeping LB farms, and from 1.2 ha to 2.4 ha (+99.8%) on buffalo-keeping RB farms. While the area of rubber, tea and other (mostly hemp) crops increased for both farming systems, corn field sizes decreased and the area covered by rice terraces remained constant between 1999 and 2009.

Table 14: Area of cultivated land (ha) per buffalo keeping households in 1999 and 2009

Farming system		**Livestock-corn based**		**Rubber based**	
Crop	**Year**	**Mean***	**SD**	**Mean***	**SD**
Rubber	1999	0.0 ^{A}	0.00	0.4 ^{A}	0.51
	2009	0.4 ^{B}	0.86	1.5 ^{B}	1.87
	change	*± ∞%*		*+275%*	
Tea	1999	0.4 ^{A}	0.32	0.2	0.30
	2009	0.8 ^{Ba}	0.49	0.2 ^{b}	0.31
	change	*+100%*		*± 0%*	
Corn	1999	0.7	0.54	0.5	0.51
	2009	0.5	0.27	0.3	0.39
	Change	*- 29%*		*- 40%*	
Rice	1999	0.3	0.17	0.2	0.18
	2009	0.3	0.12	0.2	0.16
	change	*± 0%*		*± 0%*	
Others	1999	0.1 ^{A}	0.18	0.0	0.00
	2009	0.6 ^{Ba}	0.21	0.0 ^{b}	0.00
	change	*+500%*		*± 0%*	
Total	1999	1.5 ^{Aa}	0.78	1.2 ^{Ab}	0.88
	2009	3.2 ^{Ba}	1.42	2.4 ^{Bb}	1.93
	change	*+113%*		*+100%*	

** Different superscripts indicate significant differences ($p\leq0.05$) between years (A, B – in columns) and farm types (a, b - in rows).*

Labor economy of buffalo keeping

Field preparation with the help of buffaloes is carried out between January and June on LB farms and between March and June on RB farms. During the field preparation season farmers keep their buffaloes close to the farm or on nearby fields, while the rest of the year they require feeding either through cut and carry, or guidance to proper grazing grounds, mostly in forest areas. The time investment to guide and herd buffaloes varied strongly, not only among farming systems but among individual households as well. Generally, LB households spent 5.4 ±2.7 hours per day caring for their buffaloes, while 7.0 ±1.4 hours were required on RB farms. Buffalo-related tasks were mostly carried out by older men, women and children. Table 12 displays the average time spent on different herding and feeding activities; the high standard deviations point to the unequal practice of the respective activities which can be described as follows:

- letting buffaloes graze for several days in the forest without watching them;
- fixing buffaloes on harvested rice fields and relocating them several times per day;
- a person is constantly herding buffaloes of one household (HH) for a whole day;
- a person is herding buffaloes from several HH for a whole day;
- a person is guiding buffaloes (of one or more HH) to the forest in the morning and searches and returns them to the farm in the evening;
- buffaloes remain in the stable near the house and receive cut and carry feeding;

The buffalo-keeping farmers conducted all work of field preparation with buffaloes and no machines were additionally used, even if available on farm. No sex preference existed for working buffaloes, male and female animals were used equally for field preparation. A buffalo was used to prepare crop fields for 350 ±200.1 hours per year on LB farms and 77 ±0.3 hours per year on RB farms (Table 13), whereby this includes the animals' resting time on field work days. Based on a standardized eight-hour work day with buffaloes (actual working time per day varied between 6-10 hours), 43 days (LB) and 10 days (RB) were used for ploughing fields with buffaloes. However, this calculation does not include the working hours of shared or hired buffaloes, and average yearly working time per animal might thus be higher in reality.

Buffalo marketing

Sales prices for buffaloes experienced a notable increase during the last years. Although only selling old animals, which are retired from fieldwork and not fattened in advance of sale, LB farmers earned on average 2680 Chinese RMB (~268 Euro) per buffalo in 2003 and 5580 RMB in 2008. RB farmers received 2703 RMB and 6375 RMB per retired buffalo in the respective years. These numbers indicate an overall average price increase of 108% (83% when corrected for inflation; WTO, 2012). Buffalo sales prices in 2008 were significantly different from prices in 2003 for each farm type, furthermore the price difference in 2008 differed among the two farm types as well ($p<0.05$).

Other buffalo-based outputs

Following the list of common benefits buffaloes provide to smallholder agricultural systems in South East Asia (Nanda and Nakao, 2003), milk, leather and manure need to be taken into consideration as well, but do not play an important role in the systems analyzed here: Buffalo milk has never been utilized and was not considered as product for human consumption by any respondent. Similarly, leather was not produced in the region. Buffalo skin rather is wasted and only small amounts are deep-fried to serve as snacks for kids. In contrast, the initial survey in 2008 revealed that buffalo manure was utilized by 89.4% of all buffalo keeping farmers (n=84) across the three identified farm types, and 68% stated to have need for more manure than available to them. However, at regularly field visits during one year it was observed that buffalo manure mostly was wasted: Buffalo shelters often were built near small water drains and manure was washed away during rains. Only a very low number of buffalo shelters were located near vegetable gardens, so that diluted manure could pass through them when washed into creeks. No incidence of allocating manure to fields was observed during the field stays. The small proportion of buffaloes grazing on rice fields after harvest suggests that their excreta have no significant impact on soil fertility.

Discussion

Buffalo herd sizes

The average number of animals on buffalo keeping farms in NRNNR agrees with the observation that one single buffalo can serve all work purposes on a 2 - 3 ha farm in northern China (Thu et al., 1995). Taking into account the animals required for herd restocking, an average of 2 to 3 animals per household seems reasonable. No preference of sex was found for ploughing animals, which agrees with other reports from Asia (SEA: Chantalakhana and Bunyavejchewin, 1995; India: Ranjhan, 2007), although the stronger male draught animals are recommended (Nanda and Nakao, 2003). The sex-ratio in the NRNNR herds however indicates that each farm is maintaining its own breeding unit, which is inefficient and bears the risk of inbreeding. Small genetic pools result in decreasing work power, infertility and disease susceptibility (Burrow, 1998). The reason why every single farmer keeps male adult animals probably is to avoid the reliance on a pregnant female during field preparation time, although this situation could be prevented through proper reproduction management. Optimizing breeding management could also increase the productivity of buffalo keeping in terms of better working ability (durability and power) and higher meat output

(Chantalakhana and Bunyavejchewin, 1995). Another aspect when considering productivity is herd size: based on the survey data, there was no difference in labor required for caring for the animals between farms with different herd sizes. If households would double their number of animals, labor requirements would only increase slightly and a higher productivity per animal could be gained. This option, however, is only relevant if buffaloes are kept for meat marketing purposes - and it requires secured and adequate forage resources year-round (see below).

Purposes of buffalo keeping

Traction was found to be the major reason to raise buffaloes, and selling or self consumption of meat were identified as being only additional positive side effects. These findings are congruent with several reports from the SEA+C region - in most surrounding countries buffaloes are kept for the same purpose. In Thailand, for example, about 30% of all draught power supply on small farms was contributed by buffaloes in the 1990s (Agarwal and Tomar, 1998) and the main purpose for farms in SEA to keep swamp buffaloes still is traction (Perry et al., 2002; Nanda and Nakao, 2003). Informal lending of buffaloes to neighbors in Asia was observed by Lawrence and Pearson (2002) as being common practice as well, and – although not quantified – was considered to be a significant benefit for poor farmers.

Another aspect of buffalo keeping, which is rather informal and therefore has not been mentioned by farmers, is the social benefit arising from keeping these animals. Often livestock is reported to serve as 'living bank' (Tuyen, 2001; Nanda and Nakao, 2003), which can be used to quickly generate cash in emergency cases (e.g., death or sickness of family members; Devendra and Thomas, 2002; Perry et al., 2002). Buffaloes were also reported to gain a 2.6 times higher return on investment when compared to tractors in subsistence farms from Thailand (Thu et al., 1995). The profit is generated through saving fuel costs, higher resale value and the utilization of otherwise useless crop residues. These calculations, however, are solely based on monetary values and do not include labor investment in animal care. The ability of buffaloes to reproduce, contrary to tractors, additionally reduces the farmers' risk. A broken tractor is a total loss, whereas an injured or dead buffalo still will return some money, and through reproduction a replacement will be available after some time without any further investment.

Work economy

Workload per buffalo per year calculated for NRNNR equals reports from other SEA+C countries. In Thailand, buffaloes are used for ploughing on 146 days per year, and 109 days were reported from Vietnam (Sanh et al., 1995). Comparing labor investment in animal care and return of animal work, each hour of field preparation conducted with a buffalo in NRNNR has the price of 5.6 hours of caring for the animal during the rest of the year, excluding fixed time investment such as training buffaloes and building proper housing. Those 5.6 hours, however, are of lower value than the actual ploughing time, through drastic increase of labor opportunity cost during the field preparation season and the use of “less valued“ labor, such as of old household members or women, for herding during off-season. Although, when considering labor calculations alone, tractors might be more efficient, the above-mentioned additional advantages of buffaloes still outweigh the labor aspect in subsistence-oriented farms where risk reduction is way more important than optimized short-term economy. More advanced farms, which have more resources to overcome a crisis (e.g., savings, holdings) might consider abandoning buffalo keeping and therewith gain higher labor efficiency.

Although land use patterns underwent massive changes within the last ten years – the average size of cultivated land almost doubled for both farm types still keeping buffaloes – there was no big change in the demand for traction power: A large share of the increase in cultivated land was due to the extension of tea and rubber plantations, while the expansion of the area cultivated with the two major annual crops (rice and corn) remained rather constant (rice) or decreased (corn). Rice terraces which often are situated on very steep hillsides at higher altitudes may by law not be used alternatively and are therefore not expected to vanish in the near future. These fields will continue to require traction input by buffalo draught power in areas where tractors cannot be moved from terrace to terrace. The remaining corn fields are also not expected to be converted into alternative cultivations, since local pig production, mainly relying on corn as feed, is expected to be intensified in the near future (See chapter 3). Corn fields, however, are situated on more plain sections where tractors are an appropriate tool for land preparation. Any prediction on the development of mechanized traction therefore should depart from current land use patterns and their spatial arrangement across plains, slopes and hilltops.

Meat prices and production

Although meat production is not a main reason for buffalo keeping today, the increasing animal prices, as reported in this study and confirmed for the region by several reports (Nanda and Nakao, 2003; ILRI, 2007), should strengthen the incentive of poorer farmers to produce buffalo meat for the market. Devendra and Thomas (2002) and Liang and Rahman (1985) recommended breeding dual purpose buffaloes which provide similar or better performance in ploughing, and additionally have high slaughter weight and thus will yield high sales prices. The reported price increase for live buffaloes between 2003 and 2008 reflects current developments that are observed in the whole Asian region. Prices as well as demand for meat have grown in the last years and are expected to further increase – at least for another 10 years. However, these demand increases will only have little impact on buffalo meat consumption and will mostly affect pig production in China. Buffalo meat, however, was preferred over pork by richer rural habitants in NRNNR villages but also by families who recently moved to the nearby town of Jinghong (Riedel et al., 2012), and prices as well as quantity of buffalo meat have increased on the town's wet markets during recent years (own observation). Still, the price per kg of buffalo meat was low in the studied farming systems: given that buffaloes are disposed at an age of 11 years (Nanda and Nakao, 2003) with a live weight of about 500 kg, the price per kg live weight has only been about 11 RMB in 2008. Compared to this, the live weight price of pig is above 30 RMB per kg, and about 1200 RMB can be gained from one sow and its respective offspring per year (See chapter 3). To increase meat production from buffaloes a better management is required, including shorter live spans and purposeful selection of animals. By this, breeding of buffaloes for meat production may become an interesting production branch for farmers who have the possibility to use grazing grounds close to the farm.

The future of swamp buffaloes in the study region

Our study identified swamp buffaloes as being a major asset for providing draught power on traditional farms, while meat production and trade were of secondary importance. The vast majority (92%) of the buffalo keepers was found to be poorer traditional farmers, whereas in advanced and more intensive production systems buffaloes had almost completely been abandoned in favor of tractors. The analysis of publications on buffalo population dynamics in SEA+C countries clearly reveals the interdependency of income level and the size of buffalo populations. While richer countries, such as Malaysia or Thailand, experience decreases in their buffalo numbers (-3% and -9% respectively, between 2005 and 2010), numbers increase or remain stable in economically weaker countries such as Lao and Bangladesh (+9% and +22%, respectively, between 2005 and 2010; FAO, 2012). The example of Thailand further reveals that buffalo meat still is demanded in transition countries, but is obtained from other, poorer regions, where buffaloes still are kept. Thailand annually imports cattle and buffalo meat with an estimated farm gate value of $20 to $25 million from Lao (Chapman, 1995), where buffalo numbers slightly increased in the recent past (see above; FAO, 2012). Extrapolating these observations to Xishuangbanna in China, the following development is expected: Lowland (rubber) farmers, who gain economic strength through lucrative cash-cropping, abandon buffalo keeping but continue to demand their meat for festivals and other cultural happenings, whereas the buffalo population of subsistence-oriented upland farms (of LB and PB type) will remain relatively stable and might gain importance as additional source of income through increasing meat demand from lowlands.

Conclusions

Buffaloes still contribute significantly to livelihoods of traditional farm households in southwestern China, mainly through provision of draught power at low monetary investment, and through their risk reducing traits. As long as a risk buffer is not provided otherwise, such as through investment in high value assets or opening of a bank account, buffalo keeping on respective farms is recommended. Actual trends, however, show that such farms abandon buffalo keeping too early, thereby risking impoverishment in case of shocks (e.g., rapidly increasing fuel prices, such as in 2007/2008). Only if farmers turn towards cash-crop systems where labor opportunity costs are increasing along with financial revenues, tractors will be the better choice. Appropriate consultation through official institutions is therefore required to convince poorer traditional farmers of their buffaloes' benefits. Appropriate breeding management will help increase the efficiency of buffalo keeping, both in terms of workforce and salable output of animals and meat. The time needed for animal care can be greatly reduced by shifting to group herding, which has already successfully been promoted during feedback workshops with buffalo-keepers. The current farming systems and societal customs also offer an opportunity for increasing buffalo meat production and sale in the study region, but this requires careful animal management including faster growth and earlier slaughter than observed currently.

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General Discussion

General aspects

Smallholder livestock production is a central activity of China's poorer rural population. Animals do not only serve to generate income but also have strong cultural values and the capability to absorb risks and shocks. Maximizing the economic output of livestock keeping therefore is of minor importance for these farmers. Through recent economic and political dynamics and global cultural flows, smallholder producers find themselves in very new environments today, where traditional strategies of farming and livestock keeping require careful rethinking and adoption so that the new opportunities can be used to improve their livelihoods (ILRI, 2007). While the production of relevant cash-crops and intensive livestock production have been supported by producer organizations and governmental bodies, smallholders' production of staple crop and livestock did not receive public attention and therefore lacks behind in development (Wiggins et al., 2010). Those nationwide observations have been confirmed in NRNNR, where the livestock production has been analyzed in this study. With increased intensified cash-crop production – mainly rubber – the traditional uses and purposes of livestock, such as fertilizer provision or utilization of crop-residues, are diminishing. Forced to adopt new production strategies (e.g., shifting from free ranging to penned livestock keeping), farmers today are exposed to very new challenges. Continually improved market access of formerly remotely located areas also bears new potentials as well as new constraints. Through better access to growing markets, farmers are exposed to new opportunities for income generation (Wiggins et al., 2010). While farmers can exchange goods at local markets much easier today than they could some years ago, they are also confronted with very low product prices, which are set at national and even international stock prices, and intensive farms situated far away from cities dump their cheap products on local markets. Under such circumstances it is hardly possible for smallholders to stay competitive. However, a good potential for commercialization has been identified for some products in NRNNR, especially at the market for ecologically produced food. Non-monetary values of livestock have been found to still play a role for poorer farms at higher altitudes as well, since their connection to financial infrastructure is not yet developed in a way that money could be stored in bank accounts or in other assets which provide quick liquidity in emergency situations.

Classification of Pig Production Systems and the Quantification of their Productivity

Research Objectives 1 and 2

Three distinct types of pig producers have been found among NRNNR livestock keepers. With the exception of RB farmers, who are specialized in rubber production, pigs are playing a core role in the setup of farms for own consumption and income generation. PB farms have better access to markets and raise more pigs, and therefore generate higher income than LB farms. Both types, however, are characterized by serious shortcomings in management, which is apparent through low productivity. A combination of malnutrition, uncontrolled breeding and major hygienic deficits was identified as the core weak point in those systems.

The unique reputation of SMEP on local markets (Page 32) and a nation-wide trend for ecologically produced and safe food, however, bear the opportunity for SMEP to establish as “green food” and therefore avoid direct competition with conventionally produced pork from industrialized units. Also within the research area, we found that richer cash-crop farmers in the lowland regularly purchase SME pork and weaners for further fattening. The production of pigs in NRNNR, however, has been found to be relatively ineffective under today’s circumstances; the bio-economic simulations (Page 39) have shown that at present the value of traded inputs to SMEP production exceeds the price of the product by 1:0.67. Through the optimization of culling management - assuming stability of input factors - the productivity could be increased such that the market value of outputs is higher than the market value of input factors (1:2.4). With further improvement measures, including better feeding and hygienic management, a competitive pork production could thus be reached, where the value of output factor per input increases to 1:2.45, 1:2.69, 1:2.70 and 1:3.15 fold for the four respective grower groups G1-G4. Inability of farmers to provide their pigs with sufficient amounts of quality feed was traced back to the circumstances that pigs formerly were scavenging in the NRNNR forest throughout the year and therefore mainly nourished themselves. In consequence, only small additional feed input from farmers was required. Since the present conditions of increased cash-crop farming prohibit scavenging, farmers are lacking traditional knowledge to provide pigs with adequate feed required for reproduction and growth on a daily basis. The problem of feed scarcity is a known challenge for East Asian smallholder pork production systems and possible solutions have been explored and discussed in different studies. Devendra and Sevilla (2002) point out the advantages of dual purpose crops which are especially optimized for better quality residues that lead to better feed quality for livestock. Lucila et al., (2011) have tested improved breeds of tuber root as a basis for pig fattening farms. The aspect to better distribute the sum of annually available nutrients among seasons is another approach to cope with scarce resources (Page 30).

Very large differences in the growth performance of pigs among different farms (Figure 6), which all had relatively similar management, were assumed to arise from genetic differences. Currently, the introduction of improved breeds therefore is not advisable and might only be of relevance after the current management has been improved in the mentioned aspects. The introduction of a well managed breeding strategy, however, would be an important contribution to better utilize the available genetic resources. Based on the information available, an open nucleus breeding scheme, managed by NRNNR staff or trained farmers seems to be the best fitting approach.

Current and Future Utilization of Buffaloes in NRNNR

Research Objective 3

Despite the importance of their shock-absorbing ability (ILRI, 2007) buffaloes, once being a central pillar of Chinese agricultural households, have smaller chances to play a role in future scenarios for NRNNR livestock production. Vanishing grazing grounds and regularly occurring conflicts between cash-crop producers (individual farmers as well as land-leasing companies) and buffalo keepers today are a major challenge for the latter; at the same time a growing economic power of such households renders the purchase of small tractors affordable. While farmers manage to run time consuming cut and carry systems for their pigs, such management is even more labor intensive for buffaloes through the high volume of feed required. Although buffalo meat is still popular at ceremonies and cultural happenings for richer rural inhabitants, Chinese customers outside of southern Yunnan tend to prefer beef in favor of buffalo meat; the buffalo meat market is therefore limited to the nearby surroundings of the NRNNR. This trend differs thus from richer countries and regions in SE Asia (e.g., Thailand), where the numbers of buffaloes declines while in fact buffalo meat demand increases, and the gap between demand and production is satisfied through international trade with poorer countries (Chapman, 1995). The future potential of swamp buffalo in NRNNR has been found mainly to be rooted in its cultural value and its ability to cultivate small rice terraces on steep slopes that cannot be cultivated otherwise and therefore would remain unutilized if buffaloes vanished completely. Human labor demand for buffalo keeping, however, is very high, since grazing buffaloes require constant observation and one full labor force is occupied per buffalo keeping HH every day to prevent buffaloes from penetrating into agricultural fields. Common grazing of buffaloes from different households for reduced labor load has been suggested to farmers in workshops but was rejected by participants for unknown reasons.

It therefore is a logical consequence that families desire to abandon buffalo keeping in favor of using labor-saving tractors, and the buffalo population data recorded in the surveys proved that trend. A too early abandoning of buffalo keeping by poorer households, however, bears the risk of losing their shock-absorbing ability which can put farms into serious emergency situations. Lowering the vulnerability of very poor farmers to external shocks therefore is a major task of ILRI to reduce poverty in Asia (ILRI, 2007). Only if alternative cash-sources are available to provide instant liquidity in situations of urgent needs, households are economically strong enough to abandon buffalo keeping. Such alternative cash-sources could be provided through the availability of bank branches in the reach of remote farmers, but such infrastructure actually is not in sight. It is advisable to motivate poorer farmers to continue keeping their buffaloes, against the strong trend to exchange them with tractors. Traditional farmers cropping on very steep fields might stick to buffaloes longer, but the negative effects of the huge labor requirements will probably overcome the buffaloes' benefits soon.

Policy Implications

The study has shown that smallholder livestock production suffers from long negligence through official authorities. Low animal productivity, lacking support and very little usage of modern technologies are major characteristics of NRNNR livestock production. However, the analysis of markets and the exploration of pathways for improvement of SME pig production have shown that the sector bears substantial economic potential worth being utilized. Benefits would include the support of poor rural households, meeting the national demand for meat and providing environmentally save livestock products for China's quickly growing middle class. Studies revealed that the relationship between household income and livestock possession shows an inverted U-shape. "Very poor" households often increase their income and reach a "poor" level through the expansion of livestock production. At that time, the number of livestock kept is increasing further. Through improved household economics new agricultural and non-agricultural income options are accessible for those households. Once farmers leave the "poor" status, livestock then loses importance for most households and only few intensive specialized systems remain in the livestock sector (Qiao et al., 2011). Such development is also reflected in NRNNR, where only poorer upland farmers (who have less rubber) still keep buffaloes and breed pigs. Lowland farmers, who are gaining most of their income through intensive crop-production, mostly have shrunk their livestock production and only fatten one or two pigs, mainly for self consumption without needing economic incentives. The focus for development of livestock production in NRNNR should therefore be laid on very poor farms, and on specialized poor livestock farms.

The study might raise the question whether there are any findings of significant value beyond the borders of NRNNR at regional or even national level. While all primary data have been collected in a defined geographic location, which has its very own characteristics, and therefore are only directly applicable to that fixed geographic location, the review of other studies and reports has shown that findings can be partially transferred to other areas as well. One major finding (chapter 1) was that smallholder livestock production has been neglected by policy for some decades in China. It only might be a rough figure, but a conservative extrapolation of the modeled improvements which could be achieved through a better culling management in NRNNR (chapter 3) onto national level reveals the huge potential that currently is unexploited by the country's large smallholder community: It was calculated that improved culling management can increase the annual meat output per 1 sow by roughly 30% (Table 8). As shown in Table 15 about 300 Mio smallholder pig producers (own calculations from FAO, 2012 and CSSB, 2009) contribute about 50-80% of all pigs produced in China today (CSSB, 2009). Assuming that a similar increase of output could be reached with only a fraction of all Chinese smallholder pig producers, the huge potential of developing this sector becomes obvious. China might cover large parts of its future pork demand from environmentally safe sources, provide sensitive customers with ecologically produced livestock products and in the same time increase rural wealth through large-scale support of smallholder pig farmers. The well working infrastructure of political bureaus from the central government in Beijing down to each village shows that such projects could be managed by the country. A core part for such improvement would include exploring new protein sources which could serve as pig feed, the provision of basic trainings in breeding, feeding and hygienic management and strengthening smallholder farmers' marketing power.

Table 15: Global role of China's smallholder Pig sector (2010)

Region	Numbers	Global share
World	1,375	1
China	677	0.5
Chinese Smallholder Farms	339-542	0.25-0.4

(Number of pigs produced in Million head in 2010)
Sources: FAO Stat, China Statistical Bureau

In order to prove the beneficial effects of area-wide interventions, results from this study as well as possible chances for extrapolation require further validation. Such validation should include the confirmation of data through on-farm livestock experiments and the expansion of modeling through inclusion of datasets from other geographic areas and production systems.

Development Implications

The following actions are recommended for a successful development of the smallholder livestock sector in the NRNNR:

- Allocate a dedicated livestock specialist for the future development of NRNNR;
- Create awareness for the multiple benefits of livestock among farmers;
- Livestock farmers should receive basic training in feeding and reproductive management;
- Established modern technologies such as artificial insemination should be made available for livestock keepers;
- Available plants and residues should be tested for their potential as pig feed;
- Specialized pig farmers should be trained in continuously producing a defined quantity of marketable quality pig meat;
- The quality of the existing veterinary network should be enhanced;
- If for breed/subspecies conservation reasons the swamp buffalo population of SW China is to be maintained, this requires external inducement.

Since little is known about smallholder livestock producers in China, this study serves as a pilot study beyond the borders of NRNNR as well. Given the above-discussed important role and potential of smallholder livestock keepers, and especially pork producers, the following recommendations can be derived from the present study and made for the regional and possibly the national livestock sector:

- Attention needs to be raised for the huge production potential of the smallholder livestock community for the nation's general economy and meat supply;
- Environmental and socio-economic benefits which arise from smallholder livestock keeping need to be propagated;
- The current subsidies model that targets large-scale livestock units needs restructuring in favor of small producers;
- The countrywide administrative network needs to be utilized more effectively to reach smallholders in remote locations;
- Farmers' power in their role as members of markets needs to be strengthened, for example by organizing production cooperatives.

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