Dealing with farming system diversity in Northern Ghana

Typology approaches

MSc Thesis Report

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Farming Systems Ecology Group
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Dealing with farming system diversity in Northern Ghana: typology approaches

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Cover photo: Farmers’ fields in Botingli. Credits: Katja Kuivanen
Preface and acknowledgements

This document is the result of research and analysis conducted as part of my MSc in Organic Agriculture at the Farming Systems Ecology group of Wageningen University, The Netherlands. The fieldwork component was carried out in Tamale and surrounding areas in Northern Ghana, West Africa. I am exceedingly grateful for the support received by many individuals, without whom this endeavour would not have been possible.

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Patterns of persistence – characterizing smallholder farming system diversity in Ghana’s Northern Region

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Abstract

Typologies may be used as tools for dealing with farming system heterogeneity. This is achieved by classifying farms into groups that have common characteristics, \textit{i.e.} farm types, which can support the implementation of a more tailored approach to agricultural development. This article explored patterns of farming system diversity in Ghana’s Northern Region through the classification of 80 smallholder farm households. Based on 2013 survey data, the typology was constructed using the multivariate statistical techniques of principal component analysis and cluster analysis. Results proposed six farm types, stratified on the basis of household, labour, land use, livestock and income variables, explaining the structural and functional differences between farming systems. Types 1 and 2 were characterized by relatively high levels of resource endowment and oriented towards non-farm activities and crop sales respectively. Types 3 and 4 were moderately resource endowed with income derived primarily from on-farm activities. Types 5 and 6 were resource constrained, with production oriented towards subsistence. It was found that livelihood strategies reflect the distinctive characteristics, opportunities and constraints of farm households- with poorly endowed types restricted to a ‘survival strategy’ and more affluent types free to pursue a ‘development strategy’. We conclude that a more flexible approach to typology construction, for example through the incorporation of farmer perspectives, might provide further context and insight into the drivers of diversity.

Keywords: Northern Ghana, farming systems, diversity, typology, multivariate analysis
1. Introduction

Africa is predominantly rural, with 54% of the population engaged in agriculture (FAO, 2014). The majority of farmers cultivate small, fragmented parcels of land, yet are responsible for the bulk of food production, making the smallholder farm sector a key player in the continent’s rural economy (Chamberlin, 2007; Wiggins, 2009). A farming system is defined as the complex of resources that are arranged and managed according to the totality of production and consumption decisions taken by a farm household, including the choice of crops, livestock, on-farm and off-farm enterprises (Giller, 2013; Fresco & Westphal, 1988; Köbrich et al., 2003). Smallholder farming systems are perceived to share certain characteristics which differentiate them from large-scale, profit-driven enterprises. These include: limited access to land, financial capital and inputs, high levels of vulnerability and low market participation (Chamberlin, 2007, 2008). However, the macro- and micro-level structures, drivers and constraints of these systems are shaped by constant interaction with the local social and biophysical context (Chapoto et al., 2013; Ngeleza et al., 2011; Tittonell et al., 2010). The result is farming system diversity in space (e.g. based on resource endowment), variability through time (dynamism) and multidimensionality in terms of strategy (production and consumption decisions) (Mortimore & Adams, 1999). Therefore, not all smallholders are equally land constrained, resource-poor or market oriented, and any effort to understand or develop the smallholder sector needs to start with an acknowledgement of this heterogeneity.

A practical way of dealing with farming system complexity is to stratify smallholders into subsets or groups that are homogenous according to specific criteria e.g. have broadly similar resource bases, enterprise patterns, livelihoods and constraints (Köbrich et al., 2003). Results can then be used to support the development (selection of farms), implementation (targeting and scaling-out of innovations) and monitoring (scaling up of impact assessments) of agricultural development projects (Alvarez et al., 2014; Byerlee et al., 1980; Emtage et al., 2007). Farm typologies attempt to perform such groupings; the term 'typology' designating both the science of type delineation and the system of types resulting from this procedure (Landais, 1998). The choice of differentiating criteria depends on the objective of the typology and the kind of data available (Kostrowicki, 1977; McKinney, 1969). Several studies have defined farmer classes and livelihood patterns to describe farming systems in different African countries, using a range of criteria which often overlap across regions and agro-ecological zones (see Chikowo et al., 2014 for a review on smallholder typologies in Sub-Saharan Africa). This article contributes to an existing, but relatively sparse strand of literature on farming system characterization in Ghana. Using survey data collected from seven case study villages across the country, a seminal study by Benneh (1973) derived a broad classification of the farming systems found within Ghana using the method of soil fertility maintenance and land tenure system as main discriminating criteria. Much later, focusing exclusively on Wenchi district in the Brong-Ahafo region, two qualitative studies explored farm household diversity using migrant versus native status (Adjei-Nsiah et al., 2004) and ethnicity, gender and wealth (Adjei-Nsiah et al., 2007) as variables. The latter classifications were both based on participatory methods such as wealth ranking. More recently, a 2007 study by Ghana’s Ministry of Food and Agriculture (MoFA) disaggregated farm households in 16 predominantly northern districts of the country according to their livelihood strategies, using a participatory approach (Al-Hassan & Poulton, 2009). Finally, in 2011, making use of the nation-wide Ghana Living Standards Survey 5 dataset, a study commissioned by the International Food Policy Research Institute examined the spatial disaggregation of crop production and input use patterns across the different agro-ecological zones of Ghana. However, to the authors’ knowledge, no published studies have characterized Northern Ghanaian farming systems using more formal analytical (statistical) methods.

Adopting an inductive approach, this article explores farming system variability in the case study area- Ghana’s Northern Region- through i) the identification and characterization of farm types, ii) analysis of patterns and inter-relationships between the established types and iii) consideration of the implications of findings for more efficient tailoring of agricultural support to farm type-specific challenges. In order to achieve these objectives, a typology was constructed on the basis of recent survey data and incorporated multiple, quantitative variables of farm structure (describing resource endowment) and farm functioning (describing livelihood strategies) (Irairoz et al., 2007; Tittonell, 2014). Clustering arose from multivariate analysis of these variables, using the well-known techniques of principal component analysis (PCA) and cluster analysis (CA) (for examples, see Bidogoza et al., 2009; Chavez et al., 2010; Köbrich et al., 2003; Tittonell et al., 2010). Key strengths of this approach are its reproducibility, ease of comparison across space and time and manageability- datasets can be analysed with speed and accuracy (Kostrowicki, 1977).
2. Materials and methods

2.1 Project, site selection and data sources

The research was embedded in a multi-country research-for-development program, Africa Research in Sustainable Intensification for the Next Generation (Africa RISING), supported by the United States Agency for International Development as part of the United States government 'Feed the Future' initiative (http://africa-rising.net/). Operating within a time horizon of five years (2012-2016), the program aims to create opportunities for smallholder farm households to escape hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, while conserving or enhancing the natural resource base (IITA, IFPRI & ILRI, 2012). The project is active in East and Southern Africa (Ethiopia, Tanzania, Malawi and Zambia) and in West Africa (Mali and Ghana). In each site, the challenge is to achieve the project goals while paying attention to smallholder diversity within and across the rural landscapes. Therefore, identification of farm types in project regions, at the level of selected Africa RISING intervention communities, is an important first step for the program.

Africa RISING in Ghana, led by the International Institute of Tropical Agriculture (IITA), comprises the three most poverty-stricken geographical and administrative regions in Northern Ghana; namely the Northern Region, Upper East Region, and Upper West Region. In September 2013, 17 enumerators associated with Africa RISING surveyed 240 farm households across these three regions of Northern Ghana, as part of a rapid characterization or baseline study. In each region, 80 farm households were randomly selected from Africa RISING intervention communities for interviews using a structured questionnaire. Basic information on household composition and education of household members, land holdings, livestock ownership, labour use, assets, housing, production orientation, major crops and sources of income was collected. This article makes use of the resulting dataset focusing exclusively on the classification of farm households in the Northern Region.

2.2 Study area

The Northern Region occupies 70 383 km² which constitutes over two fifths of the area of modern Ghana. It is divided into 20 districts with the town of Tamale as its regional capital. The region is economically poor with little industry and despite its geographical size, the current population is only about one fifth of the country total (Kelly & Bening 2007). Vegetation falls into the Guinea-Savannah zone, which is characterized by vast, low-lying areas of semi-arid grassland interspersed with savannah woodland, a dry and hot climate, uni-modal rainfall and fragile, sandy-loam soils often overlying impenetrable ironpan or laterite (Ellis-Jones et al., 2012; Wiredu et al., 2010). Three Africa RISING intervention communities were surveyed within the Northern Region; namely Botingli (9.61° N 0.79° W, Savelugu-Nanton district n=21), Kpalung (9.68° N 0.78° W, Savelugu-Nanton district, n=28) and Tingoli (9.37° N 1.01° W, Tolon-Kumbungu district, n=31) (Fig. 1). The communities are inhabited mostly by peoples of the Dagomba ethnic group, who comprise about a third of the population of the region (Ellis-Jones et al., 2012). The basic unit of social organization among the Dagomba is the farm household, centred around a ‘compound’ where the head (typically male) lives with his nuclear or extended family (Alhassan, 2009; Oppong, 1967). Livelihoods are based on small-scale, low-input, mixed crop-livestock agriculture and farmlands tend to follow the typical concentric spatial arrangement found elsewhere in Africa, comprised of nucleated human settlements in the middle, inner rings of fertile compound farms, medium distance fields, and outer rings of more distant bush farms (Yiridoe et al., 2006). Traditionally cultivated according to the bush fallow system, most farms are now under annual or permanent cultivation (Adikwu, 2014; Benneh, 1973). The main staple food crops are maize (which also doubles as a cash crop), yam and cassava. Groundnuts, rice, soybean and cowpea constitute the main cash crops. Yields are generally poor due to low and erratic rainfalls, low and declining soil fertility, lack of quality seed and land preparation equipment, high cost of inputs and labour constraints (Timler et al., 2014). Cattle, sheep, goats and poultry are kept as livestock for food, income, wealth accumulation, sacrificial purposes and to a lesser extent for their supply of inputs such as manure (used as organic fertilizer) and draught power (Ellis-Jones et al., 2012; Sansoucy et al., 1995). Productivity of animals is low due to inappropriate feeding and animal husbandry practices that result in high mortality rates, and farmers have limited access to veterinary services and improved livestock breeds. In general, the crop and livestock enterprises are weakly integrated (Timler et al., 2014).
2.3 Dataset

The survey dataset for the Northern Region contained information from 80 geo-referenced farm households across three Africa RISING intervention communities. Although the sample size was rather small, it captured the diversity in farming system features from a structural- (household composition, land area, major crops, livestock ownership, labour, assets and housing) and functional (production orientation and sources of income) perspective. From this pool of household-level information, 18 quantitative, ‘candidate’ variables for describing the characteristics and strategies of local farm households were distilled (Table 1); the choice being informed by the findings of previous studies (e.g. Marchetta, 2011, 2013; Timler et al., 2014; Tittonell et al., 2010), local expert knowledge and of course, project objectives and data availability. A subset of these household, labour, land use, livestock, food security and income-related variables (Table 1) was derived through the PCA (section 2.4.1) and then used for generating the typology.
### Table 1
Description of explanatory ‘candidate’ variables distilled from the survey dataset for typology construction and the subset of variables included in the PCA (Incl. in PCA).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Mean</th>
<th>±SEM</th>
<th>Min.</th>
<th>Max.</th>
<th>Incl. in PCA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Household</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of household</td>
<td>Number of members</td>
<td>15.2</td>
<td>0.97</td>
<td>4</td>
<td>37</td>
<td>✓</td>
</tr>
<tr>
<td>Age of household head</td>
<td>Number of years</td>
<td>48.0</td>
<td>1.61</td>
<td>21</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td><strong>Labour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total labour input&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Hours per year</td>
<td>2450.5</td>
<td>174.22</td>
<td>256</td>
<td>7048</td>
<td>✓</td>
</tr>
<tr>
<td>Hired labour ratio</td>
<td></td>
<td>0.1</td>
<td>0.01</td>
<td>0</td>
<td>0.44</td>
<td>✓</td>
</tr>
<tr>
<td>Female labour ratio</td>
<td></td>
<td>0.2</td>
<td>0.02</td>
<td>0</td>
<td>0.57</td>
<td></td>
</tr>
<tr>
<td><strong>Land use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cropped land area&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Hectares</td>
<td>3.8</td>
<td>0.24</td>
<td>0.81</td>
<td>9.31</td>
<td>✓</td>
</tr>
<tr>
<td>Maize ratio&lt;sup&gt;c&lt;/sup&gt;</td>
<td></td>
<td>0.5</td>
<td>0.02</td>
<td>0.19</td>
<td>1</td>
<td>✓</td>
</tr>
<tr>
<td>Legume ratio&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td>0.2</td>
<td>0.02</td>
<td>0</td>
<td>0.68</td>
<td>✓</td>
</tr>
<tr>
<td>Tuber ratio&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
<td>0.1</td>
<td>0.02</td>
<td>0</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>Other cereal ratio&lt;sup&gt;f&lt;/sup&gt;</td>
<td></td>
<td>0.1</td>
<td>0.01</td>
<td>0</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td><strong>Livestock ownership</strong></td>
<td>TLU&lt;sup&gt;g&lt;/sup&gt;</td>
<td>3.2</td>
<td>0.39</td>
<td>0.15</td>
<td>17.31</td>
<td>✓</td>
</tr>
<tr>
<td>Herd size</td>
<td></td>
<td>0.2</td>
<td>0.04</td>
<td>0</td>
<td>0.93</td>
<td>✓</td>
</tr>
<tr>
<td>Cattle ratio</td>
<td></td>
<td>0.6</td>
<td>0.04</td>
<td>0</td>
<td>1</td>
<td>✓</td>
</tr>
<tr>
<td>Small ruminant ratio&lt;sup&gt;h&lt;/sup&gt;</td>
<td></td>
<td>0.2</td>
<td>0.03</td>
<td>0</td>
<td>1</td>
<td>✓</td>
</tr>
<tr>
<td>Poultry ratio&lt;sup&gt;i&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Food security and income</strong></td>
<td>Months per year</td>
<td>6.6</td>
<td>0.36</td>
<td>1</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Food self-sufficiency&lt;sup&gt;j&lt;/sup&gt;</td>
<td>Percentage</td>
<td>36</td>
<td>3</td>
<td>0</td>
<td>86</td>
<td>✓</td>
</tr>
<tr>
<td>Crop sales&lt;sup&gt;k&lt;/sup&gt;</td>
<td>Percentage</td>
<td>21</td>
<td>2</td>
<td>0</td>
<td>76</td>
<td>✓</td>
</tr>
<tr>
<td>Livestock sales&lt;sup&lt;l&lt;/sup&gt;</td>
<td>Percentage</td>
<td>16</td>
<td>2</td>
<td>0</td>
<td>70</td>
<td>✓</td>
</tr>
<tr>
<td>Off/non-farm income&lt;sup&gt;m&lt;/sup&gt;</td>
<td>Percentage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>Family, hired- and exchange labour input for crop production (the sum of all reported labour per plot per household); <sup>b</sup>Land used by farmers for crop production (the sum of all reported plot sizes per household); <sup>c</sup>Share of arable land cropped to maize; <sup>d</sup>Share of arable land cropped to legumes: beans, soybeans, groundnuts, cowpeas; <sup>e</sup>Share of arable land cropped to roots and tubers: cassava and yam; <sup>f</sup>Share of arable land cropped to other cereals: rice, sorghum, millet; <sup>g</sup>Tropical Livestock Unit: livestock conversion factors based on Jahnke et al., 1987; <sup>h</sup>Share of small ruminants in total TLU (herd): goats and sheep; <sup>i</sup>Share of poultry in total TLU (herd): chickens, ducks, turkeys, pigeons and guinea fowls; <sup>j</sup>Months of the year when household food demands are met by on-farm production; <sup>k</sup>Share of crop products sold on the market; <sup<l</sup>Share of livestock products sold on the market; <sup>m</sup>Share of income derived from off/ non-farm activities.

Source: authors’ analysis of the 2013 survey data. In all the Tables and Figures that follow, the source remains the authors unless otherwise specified.
2.4 Typology construction

Two multivariate statistical techniques were employed sequentially for generating a typology of the surveyed farm households: PCA to reduce the dataset into non-correlated components and hierarchical CA for partitioning the PCA output into clusters. All analyses were executed in R (version 3.1.0) with the ade4 package (version 1.6-2, available online at: http://pbil.univ-lyon1.fr/ade-4/) and the cluster package (version 1.15.2).

2.4.1 Principal component analysis

To avoid distortions in the statistical analysis, the dataset based on candidate variables was carefully examined by evaluating missing data and identifying potential outliers. Missing information may result from errors in data collection or data entry, or from omission of responses by participants. Imputation methods and list-wise deletion were applied to deal with missing data in this study. The former involved calculation of replacement values through mean substitution while the latter entailed total deletion of observations with any missing data. Boxplots were used to detect outliers which were deleted at the risk of improving the multivariate analysis while limiting its generalizability to the entire population (Hair et al., 2010). Of the 80 farm households sampled by the survey, 70 were retained for statistical analysis. Furthermore, the magnitude of the relationships between candidate variables was assessed: highly correlated variables thought to be measuring the same latent construct were discarded and not included in the subset for PCA (Field, 2009).

Following the variable screening process, a subset of 12 variables was retained for explaining the diversity among farming systems (Table 1). After the extraction of all principal components (PC’s), the decision of how many PC’s to keep was made based on three criteria: i) According to Kaiser’s criterion, all PC’s exceeding an eigenvalue of 1.00 were initially retained (Chavez et al., 2010; Köbrich et al., 2003). This decision was cross-checked by looking at ii) the minimum cumulative percentage of variance chosen, here 60% (Table 2). The final criterion, that of iii) interpretability, was used to assess the conceptual meaning of the PC’s in terms of the apparent constructs under investigation. This was done by examining the correlations between the variables and the PC’s (Chessel et al., 2004; Husson et al., 2011); higher correlation coefficients signified a closer relationship to the PC (Lebart et al., 1995; c.f. circles of correlation from Fig. 2). In this study, loadings greater or equal to 0.50 were considered for interpretation purposes (Irairoz et al., 2007).

2.4.2 Cluster analysis

The PCA output in the form of a reduced dataset based on the retained PC’s was subjected to CA. A two-step approach was followed: first, a hierarchical, agglomerative clustering algorithm using Ward’s method was employed to define the number of groups (k), and then a non-hierarchical, partitioning algorithm (Partitioning Around Medoids) was employed to refine these k-groups. Ward’s method resulted in a range of cluster solutions, where each observation started out as its own cluster and was successively joined by similar clusters until only a single cluster remained (Reynolds et al., 2006). This agglomerative nesting process was represented by a dendrogram. In determining the optimal cluster cut-off points, a trade-off was sought between the number of clusters and the level of dissimilarity between clusters, with the objective of maximizing both intra-cluster homogeneity and inter-cluster heterogeneity (Hair et al., 2010). Furthermore, expert knowledge of farming systems in the study area was employed to support the choice of the dendrogram cut-off points, in order to select meaningful and realistic clusters. The number of clusters retained from Ward’s method was used as a starting value by the partitioning algorithm, which refined the cluster solution by iteratively re-assigning observations around representative observations or ‘medoids’, with the goal of creating the most distinct clusters possible (Reynolds et al., 2006; Rousseeuw, 1987). The non-hierarchical algorithm was performed to improve the robustness of the classification by optimizing farm distribution among clusters so as to minimize the sum of the distances of each observation from its cluster centre (Reynolds et al., 2006). To characterize the derived clusters, they were examined in terms of their inherent structure (i.e. the mean value of each variable for each cluster).

In addition, the patterns of the multivariate system, i.e. intra-group features and inter-group relationships were analysed, the identified farm types mapped and the consequences of farm type-specific characteristics and strategies for innovation targeting considered. Finally, the types were validated by an agricultural expert with an intimate knowledge of the local farming systems (former MoFA extension officer for the Northern Region).
3. Results and discussion

3.1 Multivariate analysis results

The PCA resulted in the extraction of the first five PC's explaining about 66% of the variability in the dataset (Table 2). The first PC explained the greatest part of the variation, about 19.4% of variability in the data.

### Table 2

<table>
<thead>
<tr>
<th>PC</th>
<th>Eigenvalue</th>
<th>Variance (%)</th>
<th>Cumulative Variance (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.33</td>
<td>19.4</td>
<td>19.4</td>
</tr>
<tr>
<td>2</td>
<td>2.05</td>
<td>17.1</td>
<td>36.5</td>
</tr>
<tr>
<td>3</td>
<td>1.42</td>
<td>11.8</td>
<td>48.3</td>
</tr>
<tr>
<td>4</td>
<td>1.20</td>
<td>10.0</td>
<td>58.3</td>
</tr>
<tr>
<td>5</td>
<td>0.97</td>
<td>8.1</td>
<td>66.4</td>
</tr>
</tbody>
</table>

The first component (PC 1) was closely related to the variables describing household size (sizehh) and animal resources (total TLU or tottlu and small ruminant ratio or rumratio), and less closely related to the hired labour ratio (hiredratio). Thus, it seemed to explain the human and animal capital of farm households (Fig. 2A). The second component (PC 2) correlated highly with land use variables (maize ratio or maizeratio and legume ratio or legratio) and total annual on-farm labour input (totlab). It was more weakly correlated with the cropped land area (landsizw) (Fig. 2A). The third component (PC 3) described the herd composition (poultry ratio or poultryratio) and management (livestock sales or livsales) (Fig. 2B). The fourth component (PC 4) was related to off/non-farm activities (offincome) (Fig. 2C). Finally, the fifth component (PC 5) was represented by the crop sales percentage (cropsales), giving insight into the production objectives of households (Fig. 2D). The results from the hierarchical clustering algorithm suggested a six-cluster cut-off point (Fig. 3), and the non-hierarchical algorithm re-assigned farms to the identified clusters. Thus, it emerged that the households of the study area could be grouped into six broad types contrasted by their structural (resource endowment) and functional (production objectives/ livelihood strategies) characteristics (Fig. 2E-2H and Fig. 4):

**Type 1.** Well resource endowed with large cattle herd, maize-based cropping system and ample non-farm activities

Type 1, which accounted for 11% of the sampled farm households, was dissociated from the others due to the strong discriminating power for the variables related to herd size and composition, household size and engagement in non-farm activities (Fig. 2). Thus, Type 1 comprised mainly large households (about 22 people) providing the majority of on-farm labour (96%), and the largest animal herds with on average 10 cows, 10 goats and 10 sheep. The poultry ratio was the lowest, but absolute numbers of birds kept were among the highest. The cropped area tended to be dedicated to the production of maize (50%). However, with an average cropland area of 3.6 ha, it was medium-sized compared to other farm types. Non-farm activities contributed to a large portion of the household income, with Type 1 showing the highest percentage of non-farm income in the total farm income (32%). Conversely, the percentages of crop and livestock sales were the lowest among all farm types.

**Type 2.** Well resource endowed with larger farm areas, legume and maize-based cropping system, market oriented

Type 2 comprised 10% of the sampled farm households. Land use-related variables and the crop sales variable showed high discriminating power in distinguishing Type 2 from other clusters (Fig. 2). Therefore this type was characterized by the largest farms area (average of 6.3 ha), with just over a third of the area cropped to maize (one of the lowest maize ratios among types) and another third to legumes (one of the largest legumes ratios among types). Type 2 relied heavily on the sale of crop products: more than half of all crop products were sold on the market (55%). It exhibited the second largest animal herds (on average 7 cows, 4 goats, 3 sheep and 38 poultry) and a relatively large household. Total labour input per year was high, but the hired labour ratio remained low.

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This refers to wealth-related variables such as farm size, livestock ownership and household size (Tittonell et al., 2010).
Type 3. Medium resource endowed with herd dominated by small ruminants, legume-and maize oriented, on-farm labour intensive

For Type 3, which comprised 13% of the sampled farm households, the main distinguishing features included herd composition and the total labour input per year (Fig. 2). The herd exhibited a relatively small size (2.4 TLU) and consisted mainly of small ruminants (about 80%). On average, households of this type possessed no cattle, 9 goats, 9 sheep and 31 birds. With 5.2 ha on average, this group cultivated the second largest farmed area, of which a third was cropped to maize and a third to legumes. Labour hours per year were the highest for this farm type, with a relatively large proportion of hired labour (about 8%). About 30% and 27% of crop- and livestock products were sold, respectively.

Type 4. Medium resource endowed with herd dominated by small ruminants, ample hired labour and farm income provided mostly by crop product sales

Type 4 was the largest cluster, accounting for 46% of the sample. It represented small farm households with diverse characteristics. Nevertheless, the variable of hired labour ratio differentiated it from other clusters (Fig. 2). The cultivated land area tended to be medium sized (about 3.5 ha) and dominated by maize and legumes (respectively about 41% and 30%). Almost half of all crop products were sold (45%). The size of the herd was relatively small (1.9 TLU) and was mostly comprised of small ruminants (70%). On average, farmers owned 1 cow, 6 goats, 6 sheep and 27 chickens. Total labour input was low for this farm type, especially considering the medium sized land area, but the share of hired labour was the highest at 14%.

Type 5. Resource constrained, maize-based cropping system and almost no income generated by off/non-farm activities

Type 5 included 14% of the sampled farm households, and its main differentiating characteristics related to land use variables and off/non-farm income (Fig. 2). The cluster exhibited the smallest farm areas (about 2.5 ha), mostly dominated by maize (about 74% of the arable land) and the lowest legumes proportion compared to other clusters (only 4%). This cluster also had the lowest share of off/non-farm income (about 8%). Herd size was generally quite small and animal production was centred on small ruminants and poultry (average ownership of 1 cow, 6 goats, 9 sheep and 34 birds). Total labour hours per year were relatively low.

Type 6. Severely resource constrained, with a small herd dominated by poultry, income generated from livestock product sales and off-farm activities

Type 6 was the smallest cluster, accounting for only 6% of the sampled farm households. It could be dissociated from the others due to the strong discriminating power for variables related to farm size and total annual labour input on the one hand, and herd size- and composition and livestock sales on the other (Fig. 2). Thus, Type 6 was characterized by small cropped area (2.6 ha, with about 47% allocated to maize) and the lowest total labour hours per year. The size of the herd was very small (about 0.3 TLU) and livestock consisted almost entirely of poultry (about 89%); on average, farmers of this type possessed only 1 goat and 24 birds. The percentage of supplementary income from off-farm activities was high (about 25%) but the main income resource was livestock products sales (about 42%). Furthermore, in contrast to similarly land-constrained Type 5, household size was small.
Fig. 2 PCA and CA output: circles of correlation (A-D) and clusters i.e. farm types 1-6 (E-H) in the planes PC1-PC2, PC1-PC3, PC1-PC4 and PC1-PC5. The directions and lengths of arrows within the circles show the strength of the correlations between variables, and variables and PC’s. The arrows highlighted in red represent those variables that correlate strongly (>0.60) with PC 1, whereas the arrows highlighted in green represent those variables that correlate strongly with each subsequent PC.
Fig. 3 Dendrogram (left) and associated bar plot (right) displaying a range of cluster solutions resulting from Ward’s method of CA. The dashed line shows the selected cut-off point which gave the six-cluster solution (Types 1-6). The vertical axis represents the agglomeration coefficient (the ‘height’ or distance between clusters merged at each stage).

Fig. 4 Box plots of variables for the six farm types based on: household (A), labour (B, C), land use (D-F), livestock (G-I) and income (J-L) dimensions. Box plots show cluster means (coloured squares), median values (solid horizontal lines), the interquartile range containing the middle 50% of values (box outline), 90th percentile values (whiskers) and outlier values (closed circles). The survey means for each variable are represented by the dashed line.
3.2 Patterns

Numerous studies have shown that the differentiating characteristics of farming systems are driven by site-specific opportunities and constraints that in turn are shaped by various factors beyond the household scale at the community, landscape, and regional levels (such as agro-ecology, markets, institutions, traditional land tenure and inheritance systems) (Chapoto et al., 2013; Tittonell et al., 2010, 2014; Yaro, 2010b). These differences influence the coping and adaptive strategies of farmers in the face of shocks (volatile prices, crop failure, droughts, unexpected expenditures etc.) and stresses (declining soil fertility, climate change, land scarcity etc.), as well as their interest and capacity to take advantage of potential opportunities for the sustainable intensification of their farms (Chamberlin, 2007; Yaro, 2010b). In the following sections, the determinants and implications of farming system diversity are discussed in relation to selected variables (grouped according to theme), their interrelationships and the identified farm types within the context of the case study area.

3.2.1 Household

The literature suggests that the size and composition of the domestic group varies according to the rank, occupation, wealth and maturity of its household head (Ngeleza et al., 2011; Oppong, 1967). Our analysis revealed a strong positive correlation between household size and herd size; the latter constituting an important indicator of wealth (Laube, 2007) (Fig. 2A). In particular, Type 1 farm households with larger herds that included valuable cattle, tended to exhibit above-average household sizes (Fig. 4A and G). Interestingly, Type 1 households were also headed by the oldest men (see Supplementary Material). However, while household size correlated positively to the additional wealth indicator of farm size, as reported elsewhere (e.g. Ngeleza et al., 2011), the relationship was found to be weak in the survey sample (Fig. 2A).

Studies have also found that household size correlates positively with income diversification (Marchetta, 2013; Adams et al., 2008). While results show only a very weak positive correlation between the variables of household size and off-farm income, the mean profile of the types suggests that on average, Type 1 households exhibited the highest percentage of off-farm income (Fig. 4J), implying that the sheer quantity of household members and wealth accumulated in the form of livestock might provide stronger incentives and increased capacity to branch out into non-farm activities (Marchetta, 2013).

3.2.2 Land use

Among the patrilineal Dagomba, land is inherited by the household head and typically fragmented into smaller parcels that are allocated to household members (Ohene-Yankyera, 2004; Oppong, 1967). Other less common access routes to land include purchase and borrowing (Yaro, 2010a). Results revealed differences in mean farm size across types, with Type 2 having the largest cropped land areas on average (Fig. 4D). Interestingly, Type 2 farmers were not surveyed in Botingli, the smallest intervention community (Fig. 5A). This could be due to under-coverage of Type 2 farmers (survey selection bias) or scarcity of land compounded by the close proximity of neighboring villages (Iddrisu Baba Mohammed, 2014: pers. comm.). The latter hypothesis seems plausible, given that mean surveyed farm sizes in Botingli were smaller than those of Tingoli or Kpalung.

The two crop variables retained in this study; maize ratio and legume ratio, bore a strong negative correlation to each other, suggesting that farms which dedicated large areas to maize did so at the expense of legume crops and vice versa (Fig. 2A). Furthermore, the share of land allocated to maize tended to increase as the overall cultivated area decreased (Fig. 2A). Studies in Ghana and elsewhere in rural Africa have shown that farm size correlates positively with holdings of livestock and other assets, and is a proxy for the wealth of a household, associated in turn with high-value crop production and market participation (e.g. Chapoto et al., 2013; Negash & Niehof, 2004; Tittonell et al., 2010). Results seem to indicate that less affluent households with smaller farms allocated more of their land to maize than their wealthier counterparts. For example, Type 5 households exhibited the smallest cropped areas and the highest maize ratio (Fig. 4E). Maize is the most widely consumed staple in the Northern Region and the higher proportion of this food crop in Type 5 suggests that limited land resources may be preferentially allocated for production oriented toward food security (Chamberlin, 2007; Morris et al., 1999). Legumes, on the other hand, were most abundant among some medium- and well-endowed farm households (Types 2, 3 and 4), and were weakly associated with higher shares of crop product sales (Fig. 2A). Legumes, primarily groundnuts and soybeans, are produced as cash crops (Ellis-Jones et al., 2012; Wiredu et al., 2010). Diversification into high value crops helps to spread risk and increase income,
which in turn enables re-investment into the farm (e.g. through the expansion of land holdings and livestock herds) as well as financing of the extra expenses associated with the use of improved technologies such as quality seed and mineral fertilizer (Morris et al., 1999; Wiredu et al., 2010). Well-endowed Type 1 did not follow this pattern, however. Despite exhibiting considerable capital assets in the form of livestock, mean farm sizes were relatively small and cropped mostly to maize (Fig. 4D, E and G). This may be partially explained by their above-average engagement in non-farm income-generating activities (Fig. 4J) and apparent re-investment of that income in livestock rather than land.

### 3.2.3 Livestock

The rearing of livestock is crucial in building farm household resilience to food insecurity in Northern Ghana (Quaye, 2008). Livestock represents the most important store of value for farmers and the wealth of a household can be measured by the number and species of animals owned (Dercon, 1998; Dossa et al., 2011; Marchetta, 2013). Results showed that Type 1 was notably livestock centred (Fig. 4G). Farm households in this category possessed the most animals and the largest cattle herds, followed by Type 2. Cattle are the most valuable form of livestock and may be inherited - they are rarely sold except in times of extreme shock such as crop failure or famine (Laube, 2007). The average share of marketed livestock products was also the lowest for these two farm types, demonstrating the farmers’ capacity to accumulate assets that decrease their vulnerability (Fig. 4L). According to the literature, it is common for farmers to gradually stock their herds in response to favourable agricultural seasons when proceeds from crop sales may be re-invested in livestock (e.g. Tittonell, 2014). In addition to being stores of wealth that provide a buffer against shocks, the large cattle herds owned by Types 1 and 2 offer manure, thus putting these farmers at an advantage in terms of agronomic practices that may lead to improved soil fertility and crop productivity (Bellwood-Howard, 2012; Chikowo et al., 2014; Morris et al., 1999).

Small ruminants are less valued but are more commonly owned in the Northern Region due to their hardy and prolific nature. They may also be sold during stressful periods for immediate cash to purchase food or pay medical bills, for example (Laube, 2007). Except for Type 6, mean small ruminant numbers tended to be quite similar across farm types. The ratios, however, were highest for medium- to low resource endowed Types 3, 4 and 5 (Fig. 4H).

Finally, almost all the sampled farm households kept a flock of family poultry which serves as a source of quick cash, (sacrificial) gifts, and protein-rich food (Laube, 2007). Results indicated that the mean poultry ratio tended to increase as farm resource endowment decreased (Fig. 4I). Furthermore, the variables of poultry ratio and livestock sales were strongly positively correlated (Fig. 2B). Keeping poultry is financially economical for smallholders because little input (land, labour, capital) is required for the maintenance of a flock. This enables even those of the poorest strata in rural communities to make a profit from the sale of poultry products (Guéye, 2000). Type 6 exemplified this - it was characterized by a near total absence of any livestock besides poultry, while exhibiting the highest percentage of livestock sales (Fig. 4G, I and L). Tellingly, food self-sufficiency was also lowest for this type (see Supplementary Material), suggesting that the liquidation of livestock assets represented a coping strategy to cover household needs. Additionally, these farmers generally lack access to animal traction and organic fertilizers, resulting in low productivity of crop production which may further exacerbate food insecurity (Tittonell, 2014; Wiredu et al., 2010).

### 3.2.4 Labour

In Northern Ghana labour is an important factor of agricultural production, and a combination of family, hired and communal exchange labour are used (Quaye, 2008). Family labour is based on kinship ties and considered to be the traditional backbone of the rural workforce. The exchange labour system takes the form of ‘work gangs’- farmers who pool their labour, taking turns working in different members’ fields (Alhassan & Pouton, 2009). Wage labourers are hired on a seasonal basis for activities such as labour-intensive land preparation (Ngeleza et al., 2011). Results revealed a weak negative correlation between the hired labour ratio and household size (Fig. 2A). Type 4 was strongly determined by these variables and therefore exhibited the smallest households on average, and correspondingly highest share of hired labour (Fig. 4A and C). This can be explained if household size is taken as a proxy for family labour availability, thereby positioning the hiring of help as a way to deal with labour shortage (Mensah, 2014; Wiredu et al., 2010). However, a healthy exchange labour system exists in the study area (Iddrisu Baba Mohammed, 2014: pers. comm.), which seemed to absorb most labour demands, thus keeping the mean hired labour ratio low across farm types. Nevertheless, while
hired labour typically constitutes only a small share of total on-farm labour; its use is still widespread in Ghana, even among low-income households (Chamberlin, 2007; Duncan & Howell, 1992). This was demonstrated by the fact that despite being severely resource constrained, all Type 6 farm households still reported hiring in some labour (Fig. 4C). Results also suggested that total on-farm labour input per year (family-, exchange and hired labour) was highest amongst households with larger cropped areas and/or animals herds (Types 1, 2 and 3), presumably due to the correspondingly higher work and maintenance requirements (Jayne et al., 2003).

Finally, the variables of total labour input and legume ratio were positively correlated (Fig. 2), probably attributable to the higher labour-intensity required for legume (especially groundnut) cultivation (Franke et al., 2010).

Fig. 5 Maps showing the spatial distribution of identified farm types in the Africa RISING intervention communities: Botingli (A), Kpalung (B) and Tingoli (C).

3.2.5 Income

Shortfalls in agricultural production are common in the harsh agro-ecological conditions of the Northern Region, compelling rural households to diversify their livelihoods (Ellis, 2000; Chapoto et al., 2013; Owusu et al., 2011). Income may be sourced from farm (crop and livestock income), off-farm (agricultural income), and non-farm activities (non-agricultural income) (Ellis, 1998). Recorded sources of off-farm income in the case study area included casual wage labour on other farms, while non-farm income sources included trading, remittances, artisanal activities, salaried work and transport services (in order of recorded frequency). Nevertheless, dependence on off/non-farm income sources was found to be quite low among most farm types (Fig. 4J). This may be explained in part by the remoteness and associated dearth of off-farm opportunities in the Northern Region, compared to the rest of the country (Chamberlin, 2008; Kelly & Bening, 2007). However, for high resource endowed Type 1, the average share of off/non-farm income was exceptionally high at 32%, and for low resource endowed Type 6 the corresponding percentage was also relatively high at 25% (Fig. 4J). Research on rural livelihood strategies suggests that more affluent farmers may be better disposed to participate in non-farm work (Owusu et al., 2011) and as incomes increase, farm households tend to shift their investments to non-agricultural activities (Adjei-Nsiah et al., 2007; Wiredu et al., 2010). According to the survey data, the majority of the Type 1 farmers were involved in trading of one kind or another. Less affluent households, on the other hand, tend to depend on agriculture or are generally limited to low-paid activities in the non-farm sector, such as seasonal work as hired labourers on the farms of wealthier neighbours (Chamberlin, 2008; Ellis, 2003; Marchetta, 2013; Reardon, 1997). However, none of the Type 6 farmers indicated involvement in casual labour. On the other hand, a third were recipients of remittances, a complementary source of income resulting from rural-urban migration. Migrant households are reportedly smaller (Davis et al., 2007; Adams et al., 2008) and labour constrained (Adaku, 2013) due to out-migration of able-bodied household members- characteristics consistent with Type 6.
Results also pointed to a weak negative correlation between the variables of off/non-farm income and crop sales (Fig. 2D). Among the more commercially oriented farms with higher shares of marketed produce, such as Types 2, 3 and 4, lower percentages of off/non-farm income were observed, presumably because supplementary income was less essential for meeting basic household needs. Finally, analysis of the spatial allocation of farm types revealed that 75% of the Type 1 farm households were located in Tingoli, a community situated in close proximity to the market town of Nyankpala in Tolon-Kumbungu, which is also the base of a number of agricultural research and development institutions (Fig. 5C). The distance to market can be used as a determinant of non-farm income (Marchetta, 2013), while travel out of the community to urban areas provides exposure to new information and technologies (Morris et al., 1999). This finding suggests, therefore, that superior access to expert knowledge on improved farming practices as well as off/non-farm opportunities may have played a role in the developmental trajectory of farm households in Tingoli.

### 3.3 The typology as a framework for innovation targeting

The communities of the case study area comprise farming systems with heterogeneous characteristics, constraints and opportunities. The suitability of potential agricultural interventions and innovations should therefore be assessed in relation to type-specific farm household capacities, using the established typology as a framework (Emtage et al., 2007; Norman & Collinson, 1985; Tittonell et al., 2010). The following sections reflect on this.

The typology revealed that 21% of the sampled farm households were relatively well endowed, comprising Types 1 and 2. It appears that endowed households employ a broader range of strategies against production-related risks; such as diversification into higher value crops, collective marketing, (bulk) purchase of inputs, and the judicious sale of some assets (Derccon, 2002; Quaye, 2008; Wiredu et al., 2010). Furthermore, their characteristics may facilitate wider exploration of opportunities for farm development (Type 2) as well as ‘stepping out’ (Dorward et al., 2009; Tittonell et al., 2010) into non-farm activities (Type 1). This has implications for innovation targeting. For example, the large farm sizes of Type 2 allude to greater investment in on-farm activities, and thus better incentives for adoption of improved agricultural technologies and practices (Morris et al., 1999). The larger household sizes associated with Type 1, in turn, may increase the likelihood of experimentation with diverse crop combinations and varieties in order to accommodate the diverse preferences of household members (Bellwood-Howard, 2012; Etwire et al., 2013). Additionally, these farm types could be encouraged to adopt practices that ensure more efficient collection, storage, and use of the manure supplied by their large cattle herds (Quansah et al., 2001). Importantly; due to inter-household interactions, innovations that are taken up by more affluent farm households may have (unintended) effects beyond the spaces in which they operate. For example, if a farmer invests in a tractor, he or she might hire out that tractor to other farmers in the community for a nominal fee, thus conferring ‘spillover’ benefits to those who cannot afford to purchase a tractor (Chapoto et al., 2013).

The largest share of the surveyed farm households were classified as moderately endowed (59 %), comprising Types 3 and 4. According to the 2007 MoFA study which disaggregated smallholders in 16 districts of Northern Ghana depending on their livelihood strategies, medium endowed farmers pursue a ‘development strategy’ (Devereux, 2008). This strategy was based on saving through livestock (with resources acquired from crop sales or livestock husbandry) leading to both farm and off/non-farm investment along with increased responsiveness to commercial farming opportunities. Our study revealed a similar pattern, with Types 3 characterized by medium sized small ruminant herds, moderate to large farm areas allocated to cash crops and some sales of assets. Type 4 exhibited comparable features, albeit at smaller dimensions. These types could be described as ‘stepping up’ (Dorward et al., 2009; Tittonell et al., 2010). In terms of targeting, then, opportunities for agricultural expansion and optimization may be investigated, especially for more vulnerable and heterogeneous Type 4 which represents the bulk of the surveyed households and appears to be straddling the boundary between low and medium endowment. However as previously described, the small households of the latter tend to limit the manpower available for on-farm labour, thus driving up the hired labour ratio. This should be taken into account if potentially labour-intensive technologies or practices are to be promoted, such as legume production intensification (Franke et al., 2010). Regarding livestock integration, the majority of medium resource endowed farmers do not own any cattle or use kraals, therefore innovations such as the use of compost as a soil amendment or the procurement of donkeys as a low-cost alternative for transportation and tillage traction, as suggested by Bellwood-Howard (2012), may be considered.
Low resource endowed households comprised 20% of the surveyed sample and were represented by Types 5 and 6. These seemed to correspond to the ‘poor’ and ‘vulnerable’ groups identified by MoFA (2007) respectively; considered to be particularly exposed to risk as a result of constrained resources (typically a few inherited assets). These farm households could be described as ‘hanging in’ (Dorward et al., 2009; Tittonell et al., 2010); a situation where vulnerability reduces possibilities for saving and investment, and maintenance of the current livelihood through subsistence farming is the priority. When hit by a shock, they may be forced to adopt a ‘survival strategy’ simply in order to cover immediate expenses (Devereux, 2008). Invariably, this implies the sale of household valuables such as livestock, food rationing, petty trade, cheap wage labour, migration, withdrawal of children from school or reliance on communal support networks for assistance (Alhassan & Pouton, 2009; Chamberlin, 2008; MoFA, 2007; Quaye, 2008). Tactics such as these often result in a downward spiral, reducing even further any opportunities to climb out of the ‘poverty trap’ (Tittonell, 2014). The poorest households thus face the strongest constraints to investing in new technologies and therefore, interventions should focus on alleviating basic challenges such as food insecurity, while innovations should be geared towards improving these farmers’ ability to accumulate capital and reinvest in their farms (Chapoto et al., 2013). For example, low resource endowed households tend to struggle to achieve food self-sufficiency (Fig 6 and Supplementary Material), often selling their produce immediately after harvest when prices are lowest to meet immediate cash needs, as well as purchasing food supplies for the rest of the year (Tittonell, 2014). Better postharvest storage facilities may benefit such farmers, allowing them to both store produce for home consumption as well as postpone (part of) the sale of their harvest until later in the season when prices are higher (Morris et al., 1999; Quaye, 2008). Furthermore, because poorer farmers tend to depend on wealthier cattle owners for animal traction and manure (Tittonell, 2014), programs may investigate possibilities for redressing this imbalance through alternative tillage traction options (as described for medium endowed farmers) or the use of compost or poultry manure as fertilizer (Bellwood-Howard, 2012). Finally, while barriers to non-farm work should be reduced, thus enabling livelihood opportunities beyond the farming sector (Type 5), policies should also be geared towards dealing with loss of on-farm labour (to migration, for example – Type 6) (Marchetta, 2013).

![Graph A](image)

![Graph B](image)

**Fig. 6** The six farm types are plotted against their household size and cattle ownership (A), and their cropped land area and food self-sufficiency (B). The survey means (m) for the plotted variables are represented by the dashed lines. Encircled points are observations that deviate from the typical characteristics of their group (see text for further explanation).

The smallest identified cluster, Type 6, represents the most vulnerable group of the typology. It could be argued, then, that development efforts should prioritize these households. However, it appears that other categories of groups widely considered to be vulnerable in rural Ghana were absent from the surveyed sample, such as the landless and female-headed households (Yaro, 2010b). Of course, it is challenging to fully capture the diversity encountered in the farming systems of the study area and it is recognized that the typology is limited in its ability to accurately represent every variation that exists. Furthermore, given the small sample size, the distinction between true outliers (*i.e.* observations that were not representative of the sample, such as
positive deviants) and artificial outliers \((i.e.\ observations\ that\ were\ representatives\ of\ small,\ under-sampled\ sub-groups)\) was hard to make. Hence, a trade-off between the representative quality and level of manageable detail of the typology had to be negotiated in the classification process (Hair \textit{et al.}, 2010). Added to this is the dynamic nature of agriculture which guarantees that typologies expire— they only provide a fleeting snapshot of farm situations in time (Emtage \textit{et al.}, 2006; Kostrowicki, 1997). All these complexities are reflected in the types themselves, which should therefore be interpreted with caution. For example, while analysis of livestock ownership patterns allowed for clear differentiation between larger households that tended to own cattle (Types 1 and 2) and smaller ones that tended not to (Fig. 6A); the relationship between farm size and food self-sufficiency revealed a fuzzier reality. Figure 6B highlights a severely land-constrained Type 5 household with high food self-sufficiency, and an amply endowed Type 2 household with below-average food self-sufficiency. The atypical characteristics of these two farm households diverged from a mean profile of farm types which seemed to imply that higher resource endowed types enjoyed higher levels of food self-sufficiency than their lower resource endowed counterparts, on average (see Supplementary Material). Such cases may reflect survey inaccuracies attributable to erroneous farmer estimates, or they may reflect the limits of standard survey representations, which often fail to capture the more intangible dimensions of rural livelihoods such as (lack of) extra-household social relationships, networks, \textit{etc.} (Randall & Coast, 2014).
4. Conclusions

An exploratory approach proved useful for identifying typical farm households in Ghana’s Northern Region. Data on 12 variables describing the farming systems associated with 70 surveyed households were evaluated by multivariate statistical methods. PCA identified 5 PC’s that accounted for about 66% of the variation in the dataset. Results from the CA led to the identification of six farm types. Types 1 and 2 were the wealthiest, Types 3 and 4 were characterized by moderate levels of resource endowment, and Types 5 and 6 encompassed poorly endowed farm households.

We observed an increasing gradient in capital and resource constraints from Type 1 to Type 6. Type 1 was characterized by a high level of income diversification and seemed to be more resilient; thus facing fewer financial constraints regarding the adoption of improved technologies and practices. Type 2 depended mostly on the marketing of crop products, and is therefore possibly the most invested in maximizing the profitability of crop production. Types 3 and Type 4 adopted diversification strategies, but faced land and labour-limitations, which may impede their capacity to invest in new technologies and adopt improved agricultural practices. Types 5 and 6 were the most resource-constrained. Vulnerability can reduce their capacity to save and invest, thus limiting these households to subsistence oriented farming.

While the typology revealed the general underlying structure of farm household heterogeneity, the complex and dynamic coexistence of the diverse farming systems in space and time was only partially captured, as neither un(der)-represented groups nor system trajectories were specifically accounted for (Irairoz et al., 2007; Landais 1998). Nevertheless, analysis of the established farm types seemed to suggest that the patterns of their persistence were rooted in the self-reinforcing ‘poverty traps’ of a system which privileged wealthier over poorer farmers.

It is envisioned that, in addition to being a practical framework through which more differentiated approaches to addressing rural challenges may be assessed or designed, the established typology might also inform the academic study of heterogeneity. For example, it may be applied to assist in-depth farming systems analyses or inform further exploratory studies through the selection of representative farms for detailed characterization. It could also be used in modelling and simulation studies to evaluate potential effects of specific interventions on the farming system (Andersen et al., 2007; Köbrich et al., 2003; Landais, 1998). At the same time, it is acknowledged that instead of promoting isolated solutions or single technological innovations, strategies for lifting poorly endowed households above certain critical thresholds would have to trigger complete ‘system shifts’ in order to induce sustainable change (Tittonell, 2014).

Finally, it should be mentioned that further insight into the drivers of diversity and the mechanisms of change might be gained through incorporation of complementary perspectives on farming system diversity, for example through the participation of farmers themselves in typology construction. It has been suggested that while quantitative, objective techniques provide reproducible and generalizable results; qualitative, participatory methods potentially deliver greater depth of understanding of the complexity of local circumstances and are useful for contextualizing heterogeneity within the rural landscape (Emtage et al., 2007; Whatmore, 1994). Therefore, it is recommended that future typological studies go a step further and adopt a more flexible approach by incorporating qualitative and quantitative; participatory and statistical methods (e.g. Alvarez et al., 2014; Den Biggelaar & Gold, 1995; Pacini et al., 2014; Righi et al., 2011).
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### Supplementary Material: Mean ±SEM of clusters (farm types) on all variables

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<th>Variable</th>
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<tr>
<td>Share of sample (%)</td>
<td>11%</td>
<td>10%</td>
<td>13%</td>
<td>46%</td>
<td>14%</td>
<td>6%</td>
</tr>
<tr>
<td>Age of household head (Years)</td>
<td>57.5±4.92</td>
<td>45.4±4.37</td>
<td>49.5±4.63</td>
<td>44.5±2.32</td>
<td>50.9±4.17</td>
<td>50.5±6.95</td>
</tr>
<tr>
<td>Size of household (No.)*</td>
<td>26.4±2.06</td>
<td>17.3±1.80</td>
<td>16.1±2.30</td>
<td>11.2±1.13</td>
<td>18.3±2.84</td>
<td>10.8±2.75</td>
</tr>
<tr>
<td><strong>Land Use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cropped land area (ha)*</td>
<td>3.6±0.85</td>
<td>6.3±0.81</td>
<td>5.2±0.62</td>
<td>3.5±0.30</td>
<td>2.5±0.33</td>
<td>2.6±0.51</td>
</tr>
<tr>
<td>Maize ratio*</td>
<td>0.54±0.08</td>
<td>0.39±0.03</td>
<td>0.38±0.03</td>
<td>0.41±0.02</td>
<td>0.74±0.05</td>
<td>0.47±0.09</td>
</tr>
<tr>
<td>Other cereal ratio</td>
<td>0.10±0.05</td>
<td>0.23±0.07</td>
<td>0.07±0.03</td>
<td>0.13±0.02</td>
<td>0.12±0.06</td>
<td>0.21±0.09</td>
</tr>
<tr>
<td>Legume ratio*</td>
<td>0.15±0.07</td>
<td>0.31±0.10</td>
<td>0.32±0.05</td>
<td>0.30±0.03</td>
<td>0.04±0.02</td>
<td>0.12±0.12</td>
</tr>
<tr>
<td>Tuber ratio</td>
<td>0.19±0.05</td>
<td>0.04±0.02</td>
<td>0.14±0.03</td>
<td>0.09±0.02</td>
<td>0.09±0.04</td>
<td>0.04±0.04</td>
</tr>
<tr>
<td><strong>Livestock</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herd size (TLU)*</td>
<td>9.3±1.36</td>
<td>6.0±1.60</td>
<td>2.4±0.31</td>
<td>1.9±0.22</td>
<td>2.3±0.51</td>
<td>0.3±0.08</td>
</tr>
<tr>
<td>Cattle ratio</td>
<td>0.77±0.02</td>
<td>0.74±0.08</td>
<td>0.07±0.07</td>
<td>0.12±0.05</td>
<td>0.09±0.06</td>
<td>0.0±0.00</td>
</tr>
<tr>
<td>Small ruminant ratio*</td>
<td>0.19±0.02</td>
<td>0.19±0.07</td>
<td>0.79±0.07</td>
<td>0.70±0.04</td>
<td>0.67±0.06</td>
<td>0.11±0.11</td>
</tr>
<tr>
<td>Poultry ratio*</td>
<td>0.04±0.01</td>
<td>0.07±0.01</td>
<td>0.14±0.04</td>
<td>0.18±0.02</td>
<td>0.24±0.06</td>
<td>0.89±0.11</td>
</tr>
<tr>
<td><strong>Labour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total labour (hours year⁻¹)*</td>
<td>2403±274</td>
<td>3320±425</td>
<td>4994±378</td>
<td>1906±158</td>
<td>1847±410</td>
<td>1168±315</td>
</tr>
<tr>
<td>Hired labour ratio*</td>
<td>0.04±0.02</td>
<td>0.03±0.02</td>
<td>0.08±0.03</td>
<td>0.14±0.02</td>
<td>0.07±0.02</td>
<td>0.07±0.04</td>
</tr>
<tr>
<td>Female labour ratio</td>
<td>0.11±0.02</td>
<td>0.15±0.03</td>
<td>0.14±0.05</td>
<td>0.13±0.02</td>
<td>0.24±0.04</td>
<td>0.22±0.11</td>
</tr>
<tr>
<td><strong>Food Security</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food self-sufficiency (months year⁻¹)</td>
<td>8.1±0.74</td>
<td>9.0±1.09</td>
<td>8.2±0.80</td>
<td>5.7±0.50</td>
<td>6.2±1.06</td>
<td>4.8±1.49</td>
</tr>
<tr>
<td><strong>Income</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off/non-farm income (%)*</td>
<td>32±8.18</td>
<td>9±4.42</td>
<td>16±3.51</td>
<td>14±2.56</td>
<td>8±1.70</td>
<td>25±10.41</td>
</tr>
<tr>
<td>Crop sales (%)</td>
<td>15±0.05</td>
<td>55±0.03</td>
<td>30±0.10</td>
<td>45±0.04</td>
<td>23±0.04</td>
<td>26±0.09</td>
</tr>
<tr>
<td>Livestock sales (%)*</td>
<td>9±0.03</td>
<td>19±0.08</td>
<td>27±0.04</td>
<td>20±0.02</td>
<td>22±0.08</td>
<td>42±0.06</td>
</tr>
</tbody>
</table>

Asterisks (*) indicate variables used for construction of the typology.
A comparison of statistical and participatory clustering of smallholder farming systems – a case study in Northern Ghana

This article is submitted as:

Photo: Focus group discussion with farmers in Tingoli. Credits: Katja Kuivanen
A comparison of statistical and participatory clustering of smallholder farming systems – a case study in Northern Ghana


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Abstract

Typologies are often used to understand and capture smallholder farming system heterogeneity, and may be derived using different approaches and methods. This article aims to compare a quantitative, statistical typology based on a survey dataset and multivariate analysis, with a qualitative participatory typology based on informal group sessions and activities with local stakeholders from three communities in Northern Ghana. The statistical typology resulted in six clusters, with farm households categorized on the basis of their structural (resource endowment)- and functional (production objectives/ livelihood strategies) characteristics. The participatory typology identified five farm types, based primarily on endowment (farm size, income investment), gender and age-related criteria. While the entire household was adopted as the unit of analysis of the statistical typology, the participatory typology provided a more nuanced differentiation by grouping individual farmers; with possibly several farmer types per household (e.g. ‘small’ and ‘female farmers’) as well as ‘farm-less’ individuals as a result. Other sources of dissimilarity which contributed to limited overlap between the typologies included changes that occurred in the communities between the two data collection efforts and inaccuracies in the data. The underlying causes of the latter seemed to be mainly related to socio-cultural issues that distorted information collection in both typologies; including power and status differences between both the researchers and farmers, as well as the farmers themselves. We conclude that although statistical techniques warrant objectivity and reproducibility in the analysis, the complexity of data collection and representation of the local reality might limit their effectiveness in selection of farms, innovation targeting and out-scaling in R4D projects. In addition, while participatory typologies offer a more contextualized representation of heterogeneity, their accuracy can still be compromised by socio-cultural constraints. Therefore, we recommend to make effective use of the advantages offered by each approach by applying them in a complementary manner.

Keywords: Northern Ghana; farming systems; heterogeneity; typology; participatory research

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Graphical Abstract

Baseline survey

Selection of explanatory variables

Multivariate analysis (PCA and cluster analysis)

Statistical typology

Comparison of farm types

Diverse farming systems

Selection of farmer key informants

Group sessions (four steps)

Participatory typology

Expert knowledge

A

B

C
1. Introduction

In Sub-Saharan Africa, the primary producers of agricultural outputs are smallholder farmers, who account for 80% of all farms in the region (AGRA, 2014). Smallholders are perceived to share certain characteristics which differentiate them from larger-scale, profit-driven producers. Such characteristics include: limited access to land, financial capital and inputs, high levels of vulnerability and low market participation (Chamberlin, 2007, 2008). However, far from being homogeneous; like farms everywhere, smallholdings are adapted to the conditions of their biophysical, economic, and socio-institutional environments (Ruthenberg, 1971). In this study, a farming system is defined as the complex of resources that are arranged and managed according to the totality of production and consumption decisions taken by a farm household, including the choice of crops, livestock, on-farm and non/off-farm enterprises (Fresco & Westphal, 1988; Köbrich et al., 2003). The process of adapting to different macro- and micro-level contexts has resulted in a rich diversity of smallholder farming system configurations at all scales (i.e. household, village, region and country) across the continent (Tittonell et al., 2010; Giller, 2013). This diversity is made manifest spatially (e.g. based on resource endowment), temporally (by virtue of their openness, farming systems are dynamic) and in farmer strategies (Ruthenberg, 1971; Mortimore & Adams, 1999).

A practical way of dealing with smallholder heterogeneity is to stratify farming systems into subsets or groups according to specific criteria (Anderson et al., 2007; Van den Brand, 2011). Farm typologies attempt to perform such groupings; the term ‘typology’ designating both the science of type delineation and the system of types resulting from this procedure (Landais, 1998). Farm typologies are constructed for different purposes, such as to analyse agricultural trajectories (Iraizoz et al. 2007) or to support the development (selection of farms), implementation (targeting and scaling-out of innovations) and monitoring (scaling up of impact assessments) of agricultural development projects (Byerlee et al., 1980; Emtage et al., 2007; Alvarez et al., 2014). Creating typologies attempts a meaningful compromise between analysing single farms (no farming system is organized exactly like any other) and assuming broad categories such as smallholders in general. Nevertheless, different approaches to typology construction can yield different results and this will affect the relevance of the resulting types for involved stakeholders.

The development of farm typologies and their utility has been reviewed by Whatmore (1994) who identified three epistemological approaches to farm clustering. The first is the taxonomic or ‘positivist approach’, which defines types based on quantitative data, according to standard scientific protocols with the choice of variables usually determined by the researcher. The second approach is more explanatory and is termed the ‘relational approach’; it challenges the dominant positivist approach with its emphasis on the identification of relations between farmers and their contexts to help explain causal processes. The third is the more interpretive yet similarly unorthodox ‘folk approach’, which incorporates the qualitative, subjective processes (motivations, meaning-making etc.) behind the patterns of behaviour, relationships and strategies of the participants into the typology. In the latter, the participants themselves usually determine the criteria for grouping of farmers or farm systems. In a similar vein, Maton et al. (2005) discriminate two kinds of farm typologies: those using ‘positivist’ methods based on statistical data (Köbrich et al. 2003) and those using ‘constructivist’ methods based on expert knowledge (Landais 1998; Girard et al. 2001). Although it is acknowledged that the boundaries between these different frameworks are not rigid, the spectrum of approaches to the study of farm diversity has the positivist approach and the folk approach as its extremes (Emtage et al., 2007). The ‘etic-emic’ distinction employed by anthropologists is particularly useful for further differentiating them (Jeffrey Bentley, 2014: pers. comm.).

The positivist approach takes as its starting point theories and concepts from outside of the studied setting, regarded as meaningful and appropriate by scientists (‘etic’ perspective) (Lett, 1990). Farm diversity is studied using quantitative variables that are believed to have strong relations with the variation in the systems under investigation, and clustering arises from multivariate statistical analysis of these variables (for examples, see Bidogzea et al., 2009; Chavez et al., 2010; Tittonell et al., 2010). Strengths of this top-down approach are its reproducibility and transferability (ease of comparison across scales and contexts) (Kostrowicki, 1977). However, by depending on researcher-defined criteria, important drivers of diversity may be overlooked and the identified categories may lack meaning for farmers themselves (Van Averbeke & Mohammed, 2006; Pacini et al., 2014).
In the folk approach, the intent is to discover how members of a system perceive and classify diversity (McKinney, 1969). Constructs are expressed in terms that are meaningful and appropriate to them (‘emic’ perspective) (Lett, 1990) and as a result, data collection tends to emphasize participatory methods (for examples, see Adjei-Nsiah et al., 2007; Kong et al., 2014). The main strength of this qualitative, bottom-up approach is the attention paid to the local context, which provides room for unexpected patterns and concepts to emerge. Furthermore, the criteria of classification used by farmers usually differ in interesting ways from those used by scientists and help ensure the formulation of a typology that is rooted in local reality (McKinney, 1969; Nazarea, 2006). One of the weaknesses of the folk approach is that it lacks the authority of the scientific method. Its subjectivity renders it difficult to measure the identified categories and its specificity makes it ill-suited to generalization beyond its local boundaries (Van Averbeke & Mohammed, 2006).

This aim of this study is to compare the positivist (statistical) and folk (participatory) approaches to typology construction. Specifically, we assess the (non-)complementarity of a statistical typology described in Kuivanen et al. (2015) and a participatory typology elaborated in this paper, for characterisation of smallholder farmers from three intervention communities of an active ‘research for development’ (R4D) project in Northern Ghana. The statistical typology was generated using recent survey data, and incorporated quantitative variables of farm structure- and functioning. Clustering arose from multivariate statistical analysis of these variables, using the well-known techniques of principal component analysis and cluster analysis. The participatory typology was delineated in collaboration with local stakeholders, using their expert knowledge to establish a common reference base. This paper thus sets out to: i) describe the results of the participatory typology; ii) compare the variables of the statistical and participatory typologies, and iii) analyse the overlap between the systems of farm types. Following this, we reflect on the possible causes of the dis(similarity) between the two approaches and conclude on the insights offered by each approach in the context of agricultural development. It is envisioned that the results will support the more effective design and execution of development strategies, interventions and policies that are tailored to the different needs and opportunities of local farmers.
2. Materials and methods

2.1 Project, site selection and data sources

This research was embedded in a multi-country research-for-development (R4D) program, Africa Research in Sustainable Intensification for the Next Generation (Africa RISING), supported by the United States Agency for International Development as part of the United States government ‘Feed the Future’ initiative (http://africa-rising.net/). Operating within a time horizon of five years (2012-2016), the program is being implemented in East and Southern Africa (Ethiopia, Tanzania, Malawi and Zambia) and in West Africa (Mali and Ghana). In partnership with selected intervention communities, Africa RISING aims to create opportunities for smallholder farm households to escape hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, while conserving or enhancing the natural resource base (IITA, IFPRI & ILRI, 2012). The challenge is to achieve these goals while acknowledging smallholder diversity within the project regions and communities. Therefore, identification of farm types is an important first step.

Africa RISING in Ghana is led by the International Institute of Tropical Agriculture (IITA) and the intervention area comprises the three most poverty-stricken geographical and administrative regions in Northern Ghana, namely the Northern Region, Upper East Region, and Upper West Region (Fig. 1). In September 2013, a team of enumerators associated with Africa RISING surveyed 240 farm households across these three regions of Northern Ghana, as part of a baseline study. In each region, 80 household heads were randomly selected from Africa RISING intervention communities for interviews using a structured questionnaire. Basic information on household composition and education of household members, land holdings, livestock ownership, labour use, assets, housing, production orientation, major crops and sources of income was collected. This study makes use of the resulting dataset, but focuses exclusively on the classification of farm households in the Northern Region.

2.2 Characteristics of the case study area

The Northern Region occupies 70,383 km² which constitutes over two fifths of the area of Ghana. Divided into 20 districts with the town of Tamale as its regional capital, the region is economically poor with little industry (Kelly & Bening 2007). Vegetation falls into the Guinea-Savannah zone, which is characterized by vast, low-lying areas of semi-arid grassland interspersed with savannah woodland, a dry and hot climate, uni-modal rainfall and fragile, sandy-loam soils often overlying impenetrable ironpan or laterite (Ellis-Jones et al., 2012; Wiredu et al., 2010). Three Africa RISING intervention communities were surveyed within the Northern Region; namely Botingli (9.61° N 0.79° W, Savelugu-Nanton district n=21), Kpalung (9.68° N 0.78° W, Savelugu-Nanton district, n=28) and Tingoli (9.37° N 1.01° W, Tolon-Kumbungu district, n=31) (Fig. 1). These communities constituted the study area.

The predominant ethnic group in the study communities are the Dagomba (Table 1), who comprise about a third of the population of the Northern region (Ellis-Jones et al., 2012). Their basic unit of social organization is the farm household, physically centred around a ‘compound’ where the head (typically male) lives with his nuclear or extended family (Al-Hassan & Poulton, 2009; Oppong, 1967). Livelihoods are based on small-scale, low-input, mixed crop-livestock agriculture and villages tend to follow the typical concentric spatial arrangement found elsewhere in Africa, comprised of nucleated human settlements in the middle, inner rings of fertile compound farms, medium distance fields, and outer rings of more distant bush farms (Benneh, 1973; Yiridoe et al., 2006).

According to the traditional land tenure system, arable land inherited by the household head through paternal lineage is fragmented into smaller plots that are allocated to household members (Iddrisu Baba Mohammed, 2014: pers. comm.). While responsibility for growing the household’s maize staple crop lies with the head and is grown on his plot (the main compound farm), all household members are expected to contribute labour, so as to ensure a basic level of staple food supplies for the domestic unit (Al-Hassan & Poulton, 2009). In addition, household members cultivate different combinations of cash- and food crops on their own farms (Table 1). Produce from these farms may be consumed after the household head’s supply has finished, or sold in the event of surpluses (Bellwood-Howard, 2009). Crop yields are generally poor due to low and erratic rainfall, low and declining soil fertility, lack of quality seed and land preparation equipment, high cost of inputs and labour constraints (Timler et al., 2014).
Livestock are kept for food, income, wealth accumulation, sacrificial purposes and to a lesser extent for their supply of inputs such as manure (used as organic fertilizer) and draught power (Ellis-Jones et al., 2012; Sansoucy et al., 1995). However, productivity of animals is low due to inappropriate feeding and animal husbandry practices that result in high mortality rates, and farmers have limited access to veterinary services and improved livestock breeds. In general, the crop and livestock enterprises are weakly integrated (Timler et al., 2014). The characteristics of the communities are further summarised in Table 1.

![Map of Northern Ghana](image)

**Fig. 1** Map of Northern Ghana (inset) showing the location of the case study communities in Ghana’s Northern Region. **Source:** Authors’ mapping in ArcMap10.2.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Savelugu-Nanton</th>
<th>Kpalung</th>
<th>Tolon-Kumbugu</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Socio-economic</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>579</td>
<td>1739</td>
<td>2266</td>
</tr>
<tr>
<td>Ethnic groups</td>
<td>Dagomba</td>
<td>Dagomba, Fulani, Frafra and Mamprusi</td>
<td>Dagomba</td>
</tr>
<tr>
<td>Religion(s)</td>
<td>Islam and traditional faiths</td>
<td>Islam, traditional faiths</td>
<td>Islam, Christianity, traditional faiths</td>
</tr>
<tr>
<td>Distance to closest urban centre</td>
<td>3 km</td>
<td>7 km</td>
<td>2 km</td>
</tr>
<tr>
<td>Land availability</td>
<td>Scarce</td>
<td>Abundant</td>
<td>Scarce</td>
</tr>
<tr>
<td>Access to major markets</td>
<td>Intermediate</td>
<td>Relatively poor</td>
<td>Relatively good</td>
</tr>
<tr>
<td><strong>Production activities</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major food crops</td>
<td>Maize (Zea mays)</td>
<td>Maize, yam (Dioscorea sativa)</td>
<td>Maize</td>
</tr>
<tr>
<td>Major cash crops</td>
<td>Soybean (Glycine max) and groundnut</td>
<td>Soybean, groundnut</td>
<td>Pepper (Capsicum chinense), groundnut</td>
</tr>
<tr>
<td></td>
<td>(Arachis hypogaea)</td>
<td></td>
<td>Free grazing local livestock breeds (cattle and small ruminants), night coralling</td>
</tr>
<tr>
<td>Livestock system</td>
<td>Free grazing local livestock</td>
<td>Herding by Fulani, free grazing and night coralling (cattle and small ruminants)</td>
<td>Traction, pig husbandry</td>
</tr>
<tr>
<td></td>
<td>breeds (cattle and small ruminants), night coralling</td>
<td>(cattle and small ruminants)</td>
<td></td>
</tr>
</tbody>
</table>
2.3 Statistical typology

The Africa RISING survey for the Northern Region comprised information from 80 farm households across the three case study communities, capturing the diversity in local farming systems (Table 2). The dataset was used by Kuivanen et al., (2015) to construct a statistical farm typology.

a) Variables
From the pool of farm household-level information, 12 variables describing household, labour, land use, livestock ownership and income dimensions were distilled (Table 2). The choice of variables was informed by the findings of previous studies, project objectives and data availability.

b) Methods
Two multivariate statistical techniques were employed sequentially: principal component analysis (PCA) to reduce the dataset into non-correlated principal components (PC’s) and cluster analysis for partitioning the PCA output into clusters. For the latter, a two-step approach was followed. First, a hierarchical, agglomerative clustering algorithm using Ward’s method was employed to define the number of groups (k), and then a non-hierarchical, partitioning algorithm was employed to refine these k-groups. All analyses were executed in R (version 3.1.0) with the ade4 package (version 1.6-2, available online at: http://pbil.univ-lyon1.fr/ADE-4/) and the cluster package (version 1.15.2).

c) Results
The results of the multivariate analysis (i.e. variable correlations, PC interpretation, farm types) are illustrated in Figure 2. The PCA extracted the first five PC’s explaining about 66% of the variability in the dataset. Six farm types were identified; contrasted by their structural (resource endowment§)- and functional (production objectives/ livelihood strategies) characteristics (Fig. 2E-2H, Table 2 and Table 4). Types 1 and 2 were the wealthiest. Type 1 comprised large households endowed with sizeable cattle herds, relatively small maize-based farms and high levels of income diversification into non-farm sectors such as trading. Type 2 was represented by households with relatively large farms cropped primarily to maize and legumes. Income was mainly generated through the sale of cash crops, making this type the most market oriented. Types 3 and 4 were characterized by moderate levels of resource endowment. Type 3 comprised labour-intensive medium-to large farms dominated by maize and legumes. Livestock consisted mostly of small ruminants. Type 4 was the largest group and it exhibited structurally similar farming systems to those of Type 3, except on a smaller scale; making it more land and labour-limited. Types 5 and 6 encompassed low resource endowed farm households. Type 5 was particularly land-constrained, characterized by small farms dedicated to maize production for household consumption and almost no income-generating off/non-farm activities. Type 6 was the smallest group and represented the most poorly-endowed households, with small herds dominated by poultry, and income procured from livestock sales combined with low-paid off-farm activities. Finally, the types were validated by a local expert (former agricultural extension officer for the Northern Region). Additional details on the multivariate analysis and resulting typology are provided in Kuivanen et al. (2015).

§ This refers to wealth-related variables such as farm size, livestock ownership and household size (Tittonell et al., 2010).
Table 2
Main characteristics and heterogeneity of the farming systems in the case study area (n=80 surveyed farms) and the variables used for their categorization in the statistical typology (‘Incl. in PCA’) and the resulting farm types (1-6) and their distribution (HRE: High resource endowed; MRE: Medium resource endowed; LRE: Low resource endowed; SRC: Severely resource constrained).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Unit</th>
<th>Incl. in PCA</th>
<th>Code</th>
<th>Mean ±SEM</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Household</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of household</td>
<td>Number of members</td>
<td>✓</td>
<td>sizehh</td>
<td>15.2</td>
<td>0.97</td>
<td>4</td>
</tr>
<tr>
<td>Age of household head</td>
<td>Number of years</td>
<td></td>
<td></td>
<td>48.0</td>
<td>1.61</td>
<td>21</td>
</tr>
<tr>
<td><strong>Labour</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total labour input&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Hours per year</td>
<td>✓</td>
<td>totlab</td>
<td>2450.5</td>
<td>174.22</td>
<td>256</td>
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<tr>
<td>Hired labour ratio</td>
<td></td>
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<td>hiredratio</td>
<td>0.1</td>
<td>0.01</td>
<td>0</td>
</tr>
<tr>
<td>Female labour ratio</td>
<td></td>
<td></td>
<td></td>
<td>0.2</td>
<td>0.02</td>
<td>0</td>
</tr>
<tr>
<td><strong>Land use</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cropped land area&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Hectares</td>
<td>✓</td>
<td>landsize</td>
<td>3.8</td>
<td>0.24</td>
<td>0.81</td>
</tr>
<tr>
<td>Maize ratio&lt;sup&gt;d&lt;/sup&gt;</td>
<td></td>
<td>✓</td>
<td>maizeratio</td>
<td>0.5</td>
<td>0.02</td>
<td>0.19</td>
</tr>
<tr>
<td>Legume ratio&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
<td>✓</td>
<td>legratio</td>
<td>0.2</td>
<td>0.02</td>
<td>0</td>
</tr>
<tr>
<td>Tuber ratio&lt;sup&gt;f&lt;/sup&gt;</td>
<td></td>
<td>✓</td>
<td></td>
<td>0.1</td>
<td>0.02</td>
<td>0</td>
</tr>
<tr>
<td>Other cereal ratio&lt;sup&gt;g&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td>0.1</td>
<td>0.01</td>
<td>0</td>
</tr>
<tr>
<td><strong>Livestock ownership</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herd size&lt;sup&gt;h&lt;/sup&gt;</td>
<td>TLU&lt;sup&gt;h&lt;/sup&gt;</td>
<td>✓</td>
<td>tottlu</td>
<td>3.2</td>
<td>0.39</td>
<td>0.15</td>
</tr>
<tr>
<td>Cattle ratio</td>
<td></td>
<td>✓</td>
<td></td>
<td>0.2</td>
<td>0.04</td>
<td>0</td>
</tr>
<tr>
<td>Small ruminant ratio&lt;sup&gt;i&lt;/sup&gt;</td>
<td></td>
<td>✓</td>
<td>rumratio</td>
<td>0.6</td>
<td>0.04</td>
<td>0</td>
</tr>
<tr>
<td>Poultry ratio&lt;sup&gt;j&lt;/sup&gt;</td>
<td></td>
<td>✓</td>
<td>poultryratio</td>
<td>0.2</td>
<td>0.03</td>
<td>0</td>
</tr>
<tr>
<td><strong>Food security and income</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food self-sufficiency&lt;sup&gt;k&lt;/sup&gt;</td>
<td>Months per year</td>
<td></td>
<td></td>
<td>6.6</td>
<td>0.36</td>
<td>1</td>
</tr>
<tr>
<td>Crop sales&lt;sup&lt;l&lt;/sup&gt;</td>
<td>Percentage</td>
<td>✓</td>
<td>cropsales</td>
<td>36</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Livestock sales&lt;sup&gt;m&lt;/sup&gt;</td>
<td>Percentage</td>
<td>✓</td>
<td>livsales</td>
<td>21</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Off/non-farm income&lt;sup&gt;n&lt;/sup&gt;</td>
<td>Percentage</td>
<td>✓</td>
<td>offincome</td>
<td>16</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Main characteristics</th>
<th>Proportion in survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HRE, large cattle herd, ample off/ non-farm activities</td>
<td>11%</td>
</tr>
<tr>
<td>2</td>
<td>HRE, large farms, market orientation</td>
<td>10%</td>
</tr>
<tr>
<td>3</td>
<td>MRE, small ruminants, on-farm labour intensive</td>
<td>13%</td>
</tr>
<tr>
<td>4</td>
<td>MRE, small ruminants, ample hired labour</td>
<td>46%</td>
</tr>
<tr>
<td>5</td>
<td>LRE, maize-dominated, few off/non-farm activities</td>
<td>14%</td>
</tr>
<tr>
<td>6</td>
<td>SRC, livestock sales, ample off/non-farm activities</td>
<td>6%</td>
</tr>
</tbody>
</table>

<sup>a</sup>A ‘farm household’ within Africa RISING is defined as a group of people that work and live at least half of the time on the farm and operate under the leadership of a household head (IITA, IFPRI & ILRI, 2012); <sup>b</sup>Family, hired- and exchange labour input for crop production (the sum of all reported labour per plot per household); <sup>c</sup>Land used by farmers for crop production (the sum of all reported plot sizes per household); <sup>d</sup>Share of arable land cropped to maize; <sup>e</sup>Share of arable land cropped to legumes: soybeans, groundnuts, cowpeas; <sup>f</sup>Share of arable land cropped to roots and tubers: cassava and yam; <sup>g</sup>Share of arable land cropped to other cereals: rice, sorghum, millet; <sup>h</sup>Tropical Livestock Unit: livestock conversion factors based on Jahnke et al., 1987; <sup>i</sup>Share of small ruminants in total TLU (herd): goats and sheep; <sup>j</sup>Share of poultry in total TLU (herd): chickens, ducks, turkeys, pigeons and guinea fowls; <sup>k</sup>Months of the year when household food demands are met by on-farm production; <sup>l</sup>Share of crop products sold on the market; <sup>m</sup>Share of livestock products sold on the market; <sup>n</sup>Share of income derived from off/ non-farm activities.

Source: authors’ analysis of the 2013 survey data. In all the Tables and Figures that follow, the source remains the authors unless otherwise specified.
Fig. 2 Output of the PCA and cluster analysis: circles of correlation (A-D) and farm types 1-6 (E-H) in the planes PC1-PC2, PC1-PC3, PC1-PC4 and PC1-PC5. The directions and lengths of arrows within the circles show the strength of the correlations between variables, and variables and PC’s. The arrows highlighted in red represent those variables that correlate strongly (>0.60) with PC 1, whereas the arrows highlighted in green represent those variables that correlate strongly with each subsequent PC. Source: Kuivanen et al., (2015).
2.4 Procedure to construct the participatory typology

Towards the end of the cropping season in September 2014, the three Africa RISING intervention communities included in the 2013 baseline survey for the Northern Region were approached for collaborative formulation of a participatory typology of farming systems. Inspired by the Participatory Learning and Action approach for learning about- and engaging with communities (Pretty et al., 1995; Salomon & Engel, 1997; Lynam et al., 2007) and working closely with a native-speaker translator who also possessed an intimate knowledge of local farming systems, a procedure was developed comprising four mutually supporting steps, referred to as: ‘introduction’, ‘simple exploration’, ‘complex exploration’ and ‘convergence’. The procedure was piloted in two non-survey villages before being adjusted and finally executed in each of the three target communities in turn. The steps are summarised below.

a) Step 1: Introduction
   An introductory meeting in each community served as a platform to present the research objectives and request the cooperation of the chief and villagers. These meetings were also used to identify farmer 10 key informants (henceforth referred to as ‘farmers’) per village who represented a cross-section of the population in terms of status, age, gender and ethnicity. It was envisioned that including the viewpoints of different categories of people would enhance the research results. To gain a preliminary understanding of the local context, focus group discussions were held with the 10 farmers, where the history, demographic makeup, social structure, production, off/non-farm activities, land tenure system and public services of the communities were discussed (c.f. Table 1 for a partial summary).

b) Step 2: Simple exploration
   Participatory resource mapping was conducted with the farmers to reveal the community’s perception of how physical space and resources were used. The maps provided a valuable visual representation of socio-cultural, institutional and natural features such as sacred sites, school buildings, water bodies, livestock enclosures and arable fields. In addition, the mapping activity stimulated reflection and discussion around the link between resources in the community and the farmers as resource users. The exercise served as a primer for the following step.

c) Step 3: Complex exploration
   The different types of farming systems that exist in the communities were identified from an emic perspective. This entailed breaking down the concept of ‘farming system’ into its more tangible sub-components (e.g. household, cropping activities, livestock). The first activity thus involved delineation of categories of difference in an open brainstorming session with all 10 key informants, guided by idiomatic ‘can-openers’ (Gotschi et al., 2009) such as: ‘We look at the fingers on our hands and see that each one is different. As the fingers on our hands are different; so the [farms/ farmers/ crops etc.] of [Botingli/ Kpalung/ Tingoli] are different. What are the differences that you see amongst yourselves?’ (translated from the vernacular). The differentiating criteria that emerged from this were recorded on a flipchart and then used in a sequential manner, first classifying farming systems according to the most salient criterion/criteria and then subdividing classes on the basis of other relevant criteria. The discussion was facilitated so that a useable set of categories were agreed upon. Next, a symbol which embodied the common consent on a representative feature of each category was assigned to these identified ‘farm types’ (c.f. Table 3). Following this, the characteristics of each farm type were expounded. Additional farmer-defined secondary criteria were recorded in a matrix and where possible, for each identified criterion the different type-specific levels and quantitative ranges were obtained (c.f. Table 4). For the purposes of comparison with the statistical types, farmers were also asked to describe the farm types in terms of additional criteria according to a checklist based on Table 2 (c.f. Supplementary Material for detailed descriptions of the types). The final activity involved assigning the 80 farms included in the baseline survey to the identified types. Cards were labelled with the name of the reference person of each sampled household (typically the male household head) and given to the farmers to classify one by one by placing them in the appropriate pile on the matrix. The farm types, their prevalence in the communities and relationships to each other were discussed.

d) Step 4: Convergence
   A transect walk was chosen with farmers to pass through the main land use systems of the village. This enabled a visit to representative farms of selected farm types identified in step 3, and cross-checking of some criteria by direct observation (e.g. dwelling type, c.f. Table 4).
2.5 Comparison of the typologies

In order to assess the (non-)complementarity of the positivist (statistical)- and folk (participatory) approach, we first compared the variables resulting from the PCA and differentiating criteria determined collaboratively with farmers. We then calculated the overlap between the farm household classifications as a measure of the (dis)similarity between two given groupings (Martin et al., 2001).
3. Results and discussion

3.1 Comparison of the statistical and participatory typology

3.1.1 Participatory typology

An important result of the participatory typology was the adoption by farmers of the ‘individual’ (i.e. plot holder or farmer) as the unit of analysis. On the other hand, in the statistical typology the unit of analysis was the ‘farm household’. Nevertheless, for the sake of simplicity, we continue to refer to the statistical- and participatory types as ‘farm types’.

Delineation of a participatory typology of farming systems in collaboration with local farmers resulted in three community-specific typologies comprising five farm types in Botingli, three types in Kpalung and five types in Tingoli. In all communities, the most salient differentiating criterion was that of ‘farm size’. The most frequently identified criteria were ‘farm size’, ‘gender’ (of plot holder), ‘age’ (of plot holder) and ‘income investment’ (Table 4). This enabled synthesis of the community-specific typologies into one global typology for the case study area comprising five farm types, each represented by selected farmer-defined symbols (Table 3). Several other secondary criteria were identified and these are summarised in Table 4.

Characterization of the resulting farm types revealed that Types A-C exhibited a trend similar to that demonstrated in the statistical typology: the gradient in farm size (representing resource endowment) tended to be positively related to high-value crop production and asset ownership; considered to be proxies for wealth (Chapoto et al., 2013; Negash & Niehof, 2004; Tittonell et al., 2010). The farmers’ estimates of the relative proportions of these types in the study communities seemed to indicate that moderately endowed Type B constituted the second-largest group followed by resource-constrained Type C, while well-endowed Type A farmers represented only a small minority. Types D and E were unique to the participatory typology. Type D comprised the wives and young children of the farmers belonging to Types A-C and therefore constituted the largest cluster in the communities. Type E, on the other hand, constituted the smallest cluster in the communities and comprised ‘farm-less’ men. In the strictest sense, the latter group should not be categorized as a farm type as they owned no farm and their source of livelihood was mainly off-farm. However, they are included in the result due to their being recognized by the farmers as a distinct group of (deviant) individuals/farmers that nevertheless form part of the community (Table 3; Supplementary Material).
Table 3
The main characteristics of the five farm types determined using participatory methods (HRE: High resource endowed; MRE: Medium resource endowed; LRE: Low resource endowed; SRC: Severely resource constrained).

<table>
<thead>
<tr>
<th>Type</th>
<th>Symbol</th>
<th>Main characteristics</th>
<th>Type prevalence in the communities</th>
<th>Proportion in the survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>![Smiling Face]</td>
<td><em>Pukparkara</em> ('Big farmers, men'): HRE (large farm size), market-orientation</td>
<td>++</td>
<td>8%</td>
</tr>
<tr>
<td>B</td>
<td>![Hand Gesture]</td>
<td><em>Pukparsagsa</em> ('Medium farmers, men'): MRE (medium farm size), variable production orientation</td>
<td>++++</td>
<td>52%</td>
</tr>
<tr>
<td>C</td>
<td>![Hoe Symbol]</td>
<td><em>Pukparbihi</em> ('Small farmers, men'): LRE (small farm size), subsistence orientation</td>
<td>+++</td>
<td>40%</td>
</tr>
<tr>
<td>D</td>
<td>![Cooking Pot and Cutlass]</td>
<td><em>Pagba pubhi</em> ('Small farmers, women &amp; children'): LRE/ SRC (small farm size), market orientation</td>
<td>++++</td>
<td>0%</td>
</tr>
<tr>
<td>E</td>
<td>![Ear Symbol]</td>
<td><em>Suhukpion</em> ('Farm-less, men'): work on other farms as hired labour</td>
<td>+</td>
<td>0%</td>
</tr>
</tbody>
</table>

*aExamples of farm type symbols; bRelative proportion of each type: + (very small); ++ (small); +++ (medium); ++++ (large); +++++ (very large).*
Table 4
Summary of the main characteristics of the (S) statistical typology (resulting from PCA) and (P) participatory typology (farmer-defined).

<table>
<thead>
<tr>
<th>Variables</th>
<th>S</th>
<th>P</th>
<th>Statistical typology</th>
<th>Participatory typology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type 1</td>
<td>Type 2</td>
<td>Type 3</td>
<td>Type 4</td>
</tr>
<tr>
<td>Demographic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age, gender, status</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total labour input</td>
<td>✓</td>
<td>Medium</td>
<td>High</td>
<td>Highest</td>
</tr>
<tr>
<td>Family &amp; exchange/ Hired labour</td>
<td>Mostly family</td>
<td>Mostly family</td>
<td>Medium share of hired labour</td>
<td>Largest share of hired labour</td>
</tr>
<tr>
<td>Cropping system</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farm size (average)</td>
<td>✓</td>
<td>Medium</td>
<td>Largest: (6.3 ha)</td>
<td>Large: (5.2 ha)</td>
</tr>
<tr>
<td>Land use and production orientation</td>
<td>Maize based</td>
<td>Legume and maize dominated</td>
<td>Legume and maize dominated</td>
<td>Legume and maize dominated</td>
</tr>
<tr>
<td>Inputs and equipment</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postharvest storage</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-sufficiency</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Livestock</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herd size and main composition</td>
<td>Largest herd (cattle)</td>
<td>Large herd (cattle)</td>
<td>Medium herd (small ruminants)</td>
<td>Small herd (small ruminants)</td>
</tr>
<tr>
<td>Socio-economic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Main income sources</td>
<td>✓</td>
<td>Non-farm income</td>
<td>Crop sales</td>
<td>Crop and livestock sales</td>
</tr>
<tr>
<td>Dwelling type</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Income investment</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal characteristics</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.1.2 Comparison of variables

Different variables/criteria were selected for statistical- and participatory clustering. While the PCA results used for clustering in the statistical typology tried to merge variables into a smaller number of dimensions, so that the clustering reflected an analysis of combined explanatory variables; in the participatory typology the criteria were used in a sequential manner first classifying farmers according to farm size and then subdividing classes on the basis of other relevant criteria. Some variables that had discriminatory value in the statistical typology were weakly represented in or absent from the participatory typology and vice versa (Table 4). Some of the variables had similar descriptive names, but their underlying meaning diverged due to interpretation as well as cultural differences, while others had different descriptive names, yet their underlying meaning converged. In the following paragraphs, the selection and representation of variables employed in the construction of the typologies is analysed.

a) Demographic
The variable of ‘household size’ was used in both typologies and proved to be a strong descriptor of wealthier Type 1 and Type A, associated with larger households (Table 4). The demographic criteria of ‘household composition’, ‘gender’, ‘status’ and ‘age’ (of plot holder) were included in the participatory typology, but not considered for delineation of statistical types. This is mostly due to the different units of analysis i.e. the farm household as a whole for the statistical typology vs. individual farmers for the participatory typology. In the participatory group discussions, farmers viewed ‘gender’ as a key determinant of farm size and differentiated between larger farms owned by men and smaller farms cultivated by women. In addition, the participatory process revealed that ‘status’ and ‘age’ were positively related and also exhibited strong discriminatory power: farmers distinguished older men (e.g. senior household heads), younger men and children. Finally, ‘household composition’ described the make-up of the domestic unit within which farmers were embedded. Distinctions were made between smaller nuclear, larger extended, polygamous and non-polygamous farm households.

b) Labour
Labour was an influential factor in the statistical typology, in particular the ‘total labour input’ variable rather than the ‘hired labour ratio’ variable (Fig. 2A; Table 4). Labour was not directly identified by farmers as a differentiating criterion, but was indirectly alluded to via the analogous criteria of ‘agricultural equipment’ and ‘farm size’. ‘Agricultural equipment’ differentiated between farmers who used hoes and cutlasses, draft animals and tractors, thus constituting a rough indicator of the labour input associated with manual vs. mechanized land preparation and other tillage practices. Secondly, the delineation of farm types based primarily on the criterion of ‘farm size’ resulted in a ‘farm-less’ category of men who worked exclusively for wages off-farm and in non-agricultural activities (see Supplementary Material). This category in itself was therefore indicative of a certain type of labour(er) that existed in the communities, as distinct from household labour, exchange labour and farmers who occasionally hired themselves out as seasonal labour.

c) Cropping system
The farm or puu was defined as the area of inherited land that a farmer cultivated (uncultivated areas were not considered to be part of the farm) (Idrisu Baba Mohammed, 2014: pers. comm.). It was described by farmers as the cornerstone of Dagomba livelihood; ‘without a farm, you are nothing’. Furthermore, according to farmers; the difference in farm sizes was the most defining feature of the farm systems in the communities (Table 3). It was explained that the size of the plot allocated to an individual depended on a number of factors such as access to resources (e.g. family- and market labour), gender of ownership (women and children were restricted to smaller farms) and the physical capabilities of farmers (related to age and health status). Interestingly, the strong discriminatory power of ‘farm size’ in the participatory typology was not reflected in the statistical typology, where the corresponding variable of ‘cropped land area’ only displayed a relatively weak correlation with PC 2 (Fig. 2A). Furthermore, the participatory clustering process revealed that resource endowment, specifically farm size, was positively related to wealth-indicating socio-economic criteria such as ‘income investment’ and ‘dwelling type’. This is not surprising, considering that expansion of the farm area is often the principal means of increasing yields (and saleable output) in low-input, land-constrained systems (Negash & Niehof, 2004; Ohene-Yankyer, 2004).

Although both typologies included various criteria to describe the cropping system, it seems that this dimension was more important for differentiating between farm types in the participatory typology. In the statistical typology, the quantitative variables of ‘maize ratio’, ‘legume ratio’ and ‘percentage crop sales’ (Table 2) corresponded to the qualitative ‘crop types’ and ‘production orientation’ criteria selected for participatory
classification (summarised under ‘Land use and production orientation’ in Table 4). ‘Crop types’ described the different crops (food- and cash) cultivated on a farm and their estimated yields, while ‘production orientation’ provided some clues about on-farm income sources by differentiating between the proportions of cash crops and food crops cultivated by farmers. In addition to these, the participatory typology also included criteria such as ‘cropping practices’ (sole cropping, mixed cropping or inter-cropping; summarised under ‘Land use and production orientation’ in Table 4), ‘agricultural equipment’ (use of tractors, animals, hoes or cutlasses for tillage), ‘agricultural inputs’ (access to- and usage of mineral fertilizer, agro-chemicals and improved seed) and ‘postharvest storage’ (traditional grain bins vs. pots or sacks). It was explained that farmers who had access to inputs were able to increase farm productivity, thus distinguishing them from those with more limited access, and thus lower yields.

Provision of food for the family was the responsibility of the household head, and food that could not be sourced on-farm had to be purchased (Al-Hassan & Poulton, 2009; Oppong, 1967). Therefore, we consider farm size to be critical for household food security (c.f. Ohene-Yankyera, 2004). By extension, it is argued that the level of seasonal food self-sufficiency enjoyed by a farm household is an important indicator of farm size, thus justifying the inclusion of ‘self-sufficiency’ as a differentiating criterion by farmers. Possibly due to farmer misestimation of seasonal food availability during survey data collection, no clear relationship between food self-sufficiency and the different farm types was found in the statistical typology (Kuivanen et al., 2015).

d) Livestock

While livestock features were key descriptors in the statistical typology, during the participatory process farmers did not include animal numbers, types or husbandry practices in their criteria for discriminating between farm types in any of the communities (Table 4). This apparent omission of livestock-related criteria may be partly explained by the traditional centrality of crop farming to Dagomba cultural identity (Idrissu Baba Mohammed, 2014: pers. comm.). Although livestock ownership has historically played a role in Dagomba livelihood strategies; manure exchange- and herding arrangements with Fulani were common until recent times (Bellwood-Howard, 2012). Nevertheless, the animal component was acknowledged in the descriptive phase of participatory typology formulation, where farmers were asked to further elaborate on the characteristics of each identified type. This revealed a positive relationship between farm size and livestock ownership: apart from animals acquired through inheritance, ownership of livestock was dependent on purchase using income generated from surplus crop product sales. Similarly to the statistical typology; herd size and composition varied between the types (see Supplementary Material), with cattle being an especially good descriptor of farmer endowment (Laube, 2007; Marchetta, 2013).

e) Socio-economic

Livelihood strategies were described in both typologies using income-related criteria (Fig. 2B, C and D; Table 4). In the statistical typology, variables were included that differentiated the income sources among households (Table 1). In the participatory typology, discrimination between food-and cash crops (represented by the ‘crop types’ and ‘production orientation’ variables) provided an indirect indication of the diversification strategies among farmers; with those oriented mainly towards cash crop cultivation assumed to derive more income from crop sales. Conversely, because livestock acted as a store of value and were rarely sold except in times of extreme shock such as crop failure or famine (Laube, 2007), such farmers were assumed to be less likely to depend on the sale of livestock for income. The omission of farmer-defined criteria related to off/non-farm activities may be partly attributed to the socio-cultural emphasis placed on agriculture as well as the relative dearth of non-farm opportunities in Ghana’s Northern Region (Chamberlin, 2008). Average dependence on off/non-farm income sources was found to be quite low among the surveyed farmers who seemed to rely more on their farm enterprise for income (Table 2).

Unequal levels of farmer financial endowment were represented by the unique socio-economic criteria of ‘income investment’, ‘dwelling type’ and ‘personal characteristics’ in the participatory typology. ‘Income investment’ described differential levels of farmer asset ownership (e.g. tractors, motorcycles and livestock) as a result of investment choices. In the statistical typology, farmer wealth investment was represented by the variables associated with ‘livestock ownership’ (Table 2). ‘ Dwelling type’ described physical differences in household compound structures by discriminating between traditional huts of mud-brick and thatch construction, and modern concrete and zinc structures. Modern compounds were considered to be more expensive to build and associated with well-endowed farmers (c.f. Pellow, 2011). Finally, ‘personal characteristics’ described the more intangible differences in health, personality and clothing style of farmers, which were understood to be positively related to wealth.
3.1.3 Classificatory overlap

The third step in the procedure for constructing the participatory typology ('complex exploration') required farmers to position the head of each household included in the baseline survey within the identified system of farm types. This facilitated later comparison of the types and allowed for an analysis of the overlap, i.e. (dis)similarity between assignments to types when comparing the statistical and participatory classifications.

First, by reorganizing the survey data into the participatory farm types, we were able to compute mean values of selected variables for each type in the statistical and participatory typologies. Comparison of these 'mean profiles' showed some similarity in terms of the inherent structure of the types: the means of selected variables for the participatory Types A, B and C were found to roughly correspond to the means of the same variables for the associated statistical types. For example, type-specific mean values for the variables of cropped land area, herd size and household size tended to be lowest for resource-constrained Types 5, 6 and Type C, and highest for the wealthier Types 1, 2 and Type A (Fig. 3A, B and C). This seems to imply that the general trends captured by the statistical typology were validated by the participatory typology.

Nevertheless, subsequent examination of the distribution of the participatory farm types across the statistical farm types revealed limited overlap when comparing the two typologies, with medium-endowed, statistical Type 4 tending to englobe almost half of the surveyed farm households (Table 2) and three of the participatory types (Fig. 3D). More specifically; the households associated with the small share of wealthier household heads assigned to Type A in the participatory typology (Table 3) were not distributed within the corresponding well-endowed statistical Types 1 and 2, as would have been expected. However, they were to be found in the medium-endowed Types 3 and 4 as well as amongst statistical outliers (Fig. 3D). More than half of the sampled household heads were identified by farmers as belonging to moderately-endowed Type B (Table 3); yet only 43% of the associated households were statistically classified as medium-endowed Type 4, while the rest were distributed amongst the other five statistical types (Fig. 3D). Furthermore, farmers assigned 40% of the sampled heads to poorly-endowed Type C (Table 3). However, only 25% of these were statistically determined as representing the corresponding resource-poor households of Types 5 and 6 (the rest were assigned to the wealthier Types 1, 2, 3 and 4). Finally, and perhaps most obviously; as the reference system of the survey included household heads who were invariably male farmers, none were classified in the unique categories of female/children (Type D) and farm-less (Type E) in the participatory typology (Table 3).
Fig. 3 Participatory (n=77 farms including 3 unclassified farms) and statistical (n=70 farms including 10 outliers) typology overlap: kernel density curves per participatory farm type (dashed lines representing the group means) and boxplots per statistical farm types (coloured point representing the group means) for the variables of cropped land area (A), herd size (B) and household size (C); and histogram showing the distribution of the participatory types across the statistical types (D).
3.2 (Dis)similarity between the farms types

The overlap between the two typologies was limited due to a range of factors: differences in the grouping approach and units of analysis, inaccuracies in the data, changes that occurred between the two data collection efforts, misidentification of household heads for classification in the participatory typology and deletion of farms as outliers during statistical analysis. These are further elaborated in the following paragraphs.

a) Approach and units of analysis

The grouping approach was fundamentally different for the statistical- and the participatory typology and this had important implications for the resulting farm types. The positivist approach of the statistical typology required measurable, quantitative data which was obtained through a structured survey; leaving intangible dimensions such as social relationships, personal characteristics of farmers etc. only partially represented (c.f. Randall & Coast, 2014). By contrast, the folk approach of the participatory typology enabled face-to-face contact and open dialogue with the farmers themselves, and the participatory farm types emerged from a host of small questions (bottom-up) rather than starting with a focus on the system itself (top-down). This emic approach yielded information that is difficult to capture in standard surveys; as illustrated by the symbols assigned to each type which served to summarise the farmers’ perspectives and also provide insight into the kind of conceptual framework farmers use to organize their realities (McKinney, 1969) (Table 3).

Furthermore, the different units of analysis (household vs. individual farmer) on the basis of which the typologies were constructed contributed to mismatch between the classifications: in the statistical typology, a given household was allocated to a farm type on the basis of information provided by the head himself; whereas in the participatory typology the surveyed household heads were assigned to farm types based on the perceptions of key informants. While surveys have the practical advantage of aggregating data at a household level (through the lens of a single reference person), they may lead to a poor representation of reality, particularly in the context of more complex, extended and/or polygamous domestic units such as those commonly found in the study area (Budlender 2003; Randall & Coast, 2014). Thus, by not interviewing multiple respondents within the household, the survey rendered certain categories of people less visible: such as those whose main occupations and income sources were off the farm, and women and children (c.f. Doss et al., 2013). For example: the wife and children associated with a resource-rich, male head would appear to be a wealthy household and classed as Type 1 in the statistical typology. The participatory typology, on the other hand, would classify the women and children as relatively resource-poor Type D. The latter approach thus provided a more nuanced differentiation, making allowance for the co-existence of multiple farm types in a single farm household and acknowledging potentially important target groups for the R4D project that were not included in the statistical typology, such as female farmers (Type D) and ‘farm-less’ men (Type E).

Nevertheless, as evidenced by a common trend in the gradient of resource endowment among types, the typologies also shared some aspects of inherent structure (i.e. similar mean profiles; c.f. 3.1.3). This complementarity between the types may be explained by the fact that the units of analysis, while telling different stories, were not divorced from each other: an individual (farmer) is usually embedded in a household.

b) Data inaccuracy

Data collected in the survey did not fully reflect reality for other reasons which include: misunderstanding by farmers of questions posed by enumerators, the difficulty of estimating quantitative variables (e.g. farm sizes, livestock numbers, age etc.), the spatially dislocated (fragmentation of farms and animal herds) yet socially interconnected context as well as local socio-cultural norms. For example, farmers assigned a household defined as moderately endowed (Type 3) in the statistical typology to a wealthier group (Type A) in the participatory typology. It was explained that the household head in question had inherited a medium-sized farm but had enlarged the area through land borrowed from neighbours. Nevertheless, only the part of the farm that had been acquired through inheritance had been recorded in the survey. Similarly, it was claimed that the same farmer possessed a sizeable herd of cattle, despite this not being apparent from the survey. This was attributed to the fact that his cattle were often tended to by relatives outside of the community. Related to the previous point, farmers explained that cattle were commonly inherited by male members of the descent group and herds were considered to be the joint property of the inheritors, making it improper for any single inheritor to ‘claim’ sole ownership. The tendency for farmers to downplay cattle numbers was also linked to the lingering legacy of a historical taxation system which penalized farmers with large animal herds (Iddrisu Baba Mohammed, 2014: pers. comm.).
Moreover, Dagomba society is hierarchical, and deference towards those of higher rank or status is expected (Oppong, 1967). During participatory classification; cultural and social (power) issues tended to distort the assessment of household heads, some of whom were considered to be of high social standing, such as the councillors to the chief (e.g. tamalnna, wulana, zoonaa), the sub chief (zakyurinna), community elders, religious leaders, teachers and ranked members of the traditional warrior class. It is possible that farmers may have felt obliged to show their respect for these individuals by assigning them to ‘superior’ types, despite the information collected in the survey revealing otherwise.

Finally, the Dagomba saying; ‘ashili nyedoo’ (‘secrets make a man’) illustrates what appeared to be a general reluctance among community members to reveal personal information. This seemed to hold particularly true when dealing with ‘outsiders’. Farmers explained that while they were distrustful of the intentions of strangers perceived as karachi (educated), they were also aware of the possibility of benefiting from such interactions: ‘If I say I am fine, then I won’t be helped’. This may have led to cases of deliberate misrepresentation of farm household situations during both survey interviews and participatory discussions.

c) Structural changes

Typologies, unless regularly updated, do not reflect the dynamic nature of farming systems or the movement of types in time (Irairoz et al., 2007; Landais, 1998). Therefore, changes to farm structure (e.g. farm size or herd size) that had occurred in the communities in the year between survey data collection and participatory analysis with farmers, may have contributed to classification discrepancies. In an example that highlights the importance of the socio-historical context of farm performance for determining type membership; a household classified as moderately endowed (Type 4) in the statistical typology was assigned to well-endowed Type A in the participatory typology. The farmers justified this decision by explaining that the household head in question was known to consistently cultivate large tracts of land, but that at the time of the survey had been forced to temporarily downsize his cropped area as a coping strategy in the face of unexpected crop failure.

Farmers emphasized this fluidity in discussions during the participatory sessions. It was remarked, for instance, that moderately-endowed Type B continuously absorbed farmers into its ranks and that the rate of ‘regression’ from resource-endowed Type A to moderately-endowed Type B was higher than the rate of ‘progression’ from resource-constrained Type C to Type B. Indeed, Type B and Type 4 encompassed the largest share of surveyed household (heads) in the participatory- and statistical typology respectively, many of which appeared to be ‘borderline cases’ that did not fit neatly into the more narrowly defined extreme types. This heterogeneity may partially account for the dispersion of Type B farms across the statistically defined categories and the apparent encapsulation of all the participatory types in Type 4 (Fig. 3).

d) Misidentification of farm households

Incorrect identification of the sampled household heads by farmers during ‘complex exploration’ (step 3) may have resulted in misclassified cases. Households were assigned to participatory types on the basis of the officially recorded, full names of their heads. This turned out to be problematic; as some household heads shared the same name, or were known to members of the community only by their nickname. This was partly addressed by referring to secondary identifiers recorded in the survey, such as tractor or television ownership. On occasion, farmers retracted their classification decisions on the premise that the household head had been misidentified. In total, 3 households remained unclassified due to doubts concerning their identity.

e) Data screening

To avoid distortions in the multivariate analysis, outliers were deleted from the survey dataset. Results of the overlap analysis seemed to suggest that some of the wealthiest farm households were expunged in the data screening process of statistical analysis as outlying observations, for example due to herd sizes which surpassed the researcher-defined cut-off point of 20 TLU. For the most part, farmers assigned the household heads associated with these statistical outliers to well-endowed Type A and moderately-endowed Type B. Interestingly, it was noted that households with herd sizes larger than the attributed threshold also exhibited farms of well above average size and were situated in the community of Kpalung, where land and the services of Fulani herdsmen were reported to be more readily available than in the communities of Botingli or Tingoli (Table 1).
4. Conclusions

Diversity precludes a uniform smallholder response to agricultural development initiatives, necessitating the design and implementation of approaches that are situationally adapted. This research was carried out in the context of a need to capture smallholder farming system heterogeneity in a way that best recognizes and balances the multiple interests, interactions and variables involved. Working with farmers from three intervention communities of an active R4D project in Northern Ghana as a case study, we compared two contrasting approaches to farming system characterization: a quantitative, statistical typology based on household-level survey data and multivariate analysis, and a qualitative participatory typology based on group sessions and activities with selected key informants. The statistical typology resulted in a general overview of the main structural- and functional trends in farm household variation, while the participatory typology provided a more nuanced analysis of diversity at the level of individual plot holders (farmers).

Our study showed dissimilarities in both type delineation and the resulting systems of types between the approaches. In the statistical typology the unit of analysis was the ‘farm household’, and multivariate analysis led to the identification of six farm types. Types 1 and 2 were the wealthiest, Types 3 and 4 were characterized by moderate levels of resource endowment, and Types 5 and 6 encompassed poorly endowed farm households. Formulation of a participatory typology resulted in five types, based on the ‘individual’ as the adopted unit of analysis. Types A-C exhibited similar trends to those found in the statistical typology; the gradient in endowment among these three types tending to be positively correlated with wealth indicators such as high-value crop production and asset ownership. Types D and E, on the other hand, were distinctive to the participatory typology and comprised the wives and young children of the farmers assigned to Types A-C and ‘farmless’ men, respectively. Furthermore, different variables were selected for statistical and participatory clustering. While the PCA results used for clustering in the statistical typology tried to merge variables into a smaller number of dimensions, so that the clustering reflected an analysis of combined explanatory variables; in the participatory typology the criteria were used in a sequential manner first classifying farmers according to farm size and then subdividing classes on the basis of other relevant criteria. Finally, analysis of the overlap between assignment of surveyed household (heads) to types when comparing the statistical and participatory classifications revealed discrepancies. These were attributed to a number of factors such as differences in the approach and units of analysis, inaccuracies in the data due to interpretation and socio-cultural (power) issues, changes that occurred between the two data collection efforts, misidentification of household heads for classification in the participatory typology and deletion of farms as outliers during statistical analysis.

We conclude that while the use of statistical techniques warrant objectivity and reproducibility in the analysis, the complexity of data collection and representation of the local reality might limit their effectiveness in selection of farms and of innovation targeting and out-scaling in R4D projects. In addition, while participatory typologies offer a more contextualized representation of heterogeneity, their accuracy can still be compromised by socio-cultural constraints. For both statistical and participatory typology approaches, the dynamic nature of farms and households, with changes that can occur either gradually or as discrete events, should be addressed more explicitly to remain relevant and effective in R4D projects. Therefore, neither the reliance on local experts as information sources, nor structured surveys are sufficient methods for the study of diversity by themselves. We concur with recommendations made elsewhere to make effective use of the advantages offered by both approaches by integrating them (Alary et al., 2002; Den Biggelaar & Gold, 1995; Pacini et al., 2013; Righi et al., 2011). Although participatory work is time-consuming; if used prior to statistical approaches, the rich insights it provides may enhance the quality of research, for example in the selection of more appropriate variables to use in multivariate analysis, improved survey design, etc. Using participatory methods in addition to statistical tools would also ensure that contrasting but complementary information from both emic and etic perspectives are included in the final output.
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**Supplementary Material: Description of farm types as defined in the participatory typology**

*Type A. Pukparkara* (‘Big farmers, men’): HRE, market-orientation

Constituting the smallest class in each community with the exception of Tingoli, where only the landless were fewer in number, farmers of this category cultivated the largest land areas of at least 4ha. In Kpalung up to 32 ha were reported to be farmed. Only 8% of survey respondents were classified as belonging to this group. Commonly headed by more mature household heads of approximately 40-60 years of age, households associated with Type A were characterized by large, polygamous families, swelled by the ranks of extended family members attracted by the relative wealth of their patron. However, younger household heads with smaller families, who had inherited ample land and resources form their late fathers, were also represented in this category. Among ‘Big Farmers’ the key objective of farming was production for market. Generally, the sale of cash crops as a primary livelihood strategy translated into allocation of the majority of land to the cash crops of the season: mainly soybeans (*Glycine max*) (Fig. S-B), rice (*Oryza sativa*) and sometimes tobacco (*Nicotiana tabacum*) as a lucrative end-of-season crop, and reservation of a smaller portion to food crops: mainly maize (*Zea mays*)- used to prepare the staple dish called *sagim or tuo zafi*, and yam (*Dioscorea*) used to prepare another common dish - *fufu* (Fig. S-A). Despite their commercial orientation, farmers typically aimed at producing enough maize grain to supply their households with food for the entire year to ensure self-sufficiency, and only considered selling surplus grain (Fig. S-L). Maize yields were generally favourable as farmers could afford to timeously apply the recommended rates of fertilizer. Since these farmers were not in a hurry to buy food in the lean season, they were also not in a hurry to sell their crops, and could thus afford to wait until market prices were high. In the meantime, grain was stored in large traditional huts called *kambong* (Fig. S-C) or in market-ready bags.

Because ‘Big farmers’ could afford to send their children to school, the pool of family labour was constrained, and thus outside labour was hired in for weeding and harvesting of labour-intensive cash crops. Up to 30 migrants or ‘Small farmers’ (Type C) might be hired per season. An exchange labour-system based on friendship, marriage ties and traditional youth work groups was also readily exploited. Income generated from crop sales allowed farmers to keep large animal herds. Most of the cattle in the communities were owned by members of this category; up to 100 head. Herds were tended by Fulani herdsmen, who were reimbursed in kind for their services, or by village children who constituted family- or exchange labour. Manure from the cattle was sometimes applied to fields as an organic soil amendment. In terms of small ruminant ownership, sheep were preferred due to their higher market price. Fowls were kept around the household compound, and slaughtered for sacrifices, funerals and honouring of guests. Livestock sales were minimized as a source of income, and limited to the sale of old or sick animals. Cash generated from crop sales was used to replace slaughtered or sold animals, and farmers aimed to invest in more cattle to expand their herds. During the off-season many ‘Big farmers’ turned to business ventures such as food-stuff trading; collecting produce from other farmers and selling this as a source of income. Other off/non-farm activities included hiring out tractor services (Fig. S-E) and participation in the transportation industry as drivers of ‘motorkings’ (motorbikes equipped with a broad cargo trailer) for example.

*Type B. Pukparsaga* (‘Medium farmers, men’): MRE, variable orientation

In all three communities, ‘Medium farmers’ comprised the second largest category. More than half of all the survey respondents were classified as belonging to this group. Farm sizes ranged from 0.8 to 4 ha, with the largest cultivated areas belonging to farmers in Kpalung community. Despite encompassing households varying in size from 6 to 30 individuals, and household heads of different ages, it was generally agreed that most ‘Medium farmers’ were young men of 25-35 years. These farmers had few dependents and many still lived under the care of their father, who, as senior household head, bore the burden of feeding his extended household. The rest of the category comprised more mature household heads between the ages of 35 and 40, with multiple wives and associated larger families.

Due to the diverse household composition among ‘Medium farmers’, there were also noticeable differences among production objectives. Nevertheless, it was agreed that most farmers produced food- and cash crops for both household consumption and market. Many younger farmers with smaller families pursued a strategy aimed at maximizing profits, for example by interspersing small amounts of food crops such as yam with cash crops. The food crops would then be used to feed the family throughout the year, or supplement the food

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supplied by the main provider; the household head. On the other hand, more mature framers with larger families generally prioritized household food security, and thus allocated most of their land to the production of staple crops. Such farmers would often estimate the amount needed to feed their families, and then sell the reserve as cash crops. Nevertheless, in case of low yields or other unforeseen shocks, food crops would be sold, thus compromising the self-sufficiency of farmers. Maize, yam and cassava (Manihot esculenta) were the preferred food crops while rice and soybean were cited as the main cash crops. Small amounts of millet (Pennisetum glaucum) were cultivated by 'Medium farmers' too. Fields were prepared using hoes, cutlasses, animal traction (Fig. S-D) and tractors hired out from the 'Big Farmers' (Type A). Postharvest storage of grain in smaller traditional storage facilities (kuchung or pupuri) enabled farmers to save food for later consumption, while surpluses and market produce were kept in bags, ready for sale towards the end of the season when prices were highest. Larger households capitalized on the family labour pool, as well as the traditional exchange labour networks. In general, where labour was hired, it was on a smaller scale than that of 'Big Farmers' (Type A), at 4-15 persons a season.

Besides contributing to food for the household in times of need, cash generated from crop sales was used for the payment of school fees, inputs and tractor services as well as motorbikes for transport. Most income, however, was invested in livestock. Typically, 'Medium farmers' did not have much livestock to begin with, but farmers could expand their herds if they managed to avoid selling their animals, ultimately accumulating enough wealth to graduate to the 'Big Farmer' (Type A) category. Farmers possessed up to 20 head of cattle, although those producing more food- than cash crops purchased fewer animals. If livestock were sold, it was because an animal was old or sick, or there was an urgent need for cash and no crops were available to sell first. The only animals bred for sale were pigs, as they were considered to be prolific breeders. However, due to the prohibition of pork consumption among a largely Muslim populace, the market was limited to a small Christian minority. Off-farm, members of this category engaged in a number of artisanal activities to support their livelihoods, such as weaving and selling of traditional zanna mats and gabga rope (Fig. S-F), tailoring of clothes and fitting of bicycles. Those who owned donkey carts fetched water from nearby dams to sell in the communities, while others collected and sold firewood, thatching grass and sticks for fencing. Some farmers engaged in small scale food trade and transportation.

Type C. Pukparbihi ('Small farmers, men'): LRE, subsistence orientation

This type constituted the largest group in Tingoli, as in Kpalung when combined with 'Small farmers, women & children' (Type D). In Botiingli, however, it was not considered to be a large group. Overall, 40% of the survey respondents across the three communities were classified as 'Small farmers (men)'. The farm type was distinguished by its relatively small cultivated areas ranging from 0.4 to 2 ha. The main crops grown were maize, sorghum (Sorghum bicolor), cassava and peppers (Capsicum chinense). A strategy of allocating the majority of farmland to food crop cultivation was pursued in order to secure household food security. Despite this, food self-sufficiency was rarely achieved. What limited crop surpluses (e.g. groundnuts (Arachis hypogaea) or peppers) were available would be dried and stored in jute sacks in the compound of the household head and sold; mainly to support purchase of inputs for farming and food for consumption (Fig. S-I). Especially during the lean season, farmers would be forced to purchase staples such as yams from the market or borrow from neighbours and other community members. Tractor services were rarely hired out by 'Small farmers (men)’-most field preparation and labour was carried out manually with a hoe and cutlass. Farmers applied fertilizer but reportedly not at the correct time due to insufficient funds, with low yields as a result. It was reported that a common scenario for maize was a timely first fertilizer application but a delayed second application due to lack of cash. To mitigate this problem, farmers sold their matured cash crops, such as groundnuts, and used the income to purchase more fertilizer, or borrowed money for the fertilizer itself in order to carry out the applications on time.

Family size- and composition were variable in this category. Small families (2-5 persons) headed by junior, newly independent household heads, were common. As family size and assets grew, such farmers commonly graduated to the 'Medium' (Type B) or 'Big farmer' (Type A) classes. In the case of larger households (>10 persons), it was reported that some were in fact previous members of the 'Big farmer category’, but due to crop failure or other shocks, were temporarily reduced to cultivating smaller areas the following season. In other cases, the pressures of large family sizes were instrumental in the household's devolvement to 'Small farmer (men)' status: as family demand for food was higher than what was harvested, this meant that surpluses became unavailable for sale thus compromising future investment into the farm, resulting in a gradual decline in the cultivated area. Household income was generally spent on food and farmers invested in
cheap modes of transport such as bicycles. Children of ‘Small farmers (men)’ were often denied the opportunity of formal education, due to unaffordable school fees.

This farm type depended on family labour and the exchange labour network. Most ‘Small farmers (men)’ could not afford to hire in labour themselves, but occasionally sold their own labour to make ends meet. In fact, this category also included most of the migratory farmers (youth) who travelled south in the off-season to sell their labour during the first cropping season in Southern Ghana from March-May**. Besides seasonal farm work, other off/ non-farm activities pursued by ‘Small farmers (men)’ included those practiced by ‘Medium farmers’ (Type B). In general, it was difficult for ‘Small farmers (men)’ to accumulate small ruminants and cattle. Nevertheless, it was not unheard-of for them to own some livestock and slowly expand their operations. Such farmers had, for instance, inherited a few head of cattle from their fathers. Sometimes farmers accumulated larger poultry flocks (Fig. S-3) but more often the birds were sold quickly for cash or food. In a good year, farmers purchased a few more animals or at least refrained from selling those that they had.

Type D. *Pagba pubihi* (‘Small farmers, women & children’): LRE, SRC, market orientation

This was identified as being the largest category in Botingli and Kpalung (in the latter combined with Type C). In Tingoli it was explained that not all the women were involved in agriculture due to land scarcity, hence the relative small size of the category there. Because only male household heads were interviewed for the survey, no respondents were reported as being representative of Type D. This category concerned the women of the community who were generally married, and their small children. The women and children thus worked together and were part of a larger household. The areas cultivated by women in the study area were between 0.1 and 0.4 ha, with individual farms often located some distance from the compound, out in the bush close to the outfields belonging to the household head. Groundnuts, okra (*Hibiscus esculentus*), soybeans, maize, sorghum, peppers, local leafy vegetables, tomatoes and cowpeas (*Vigna sinensis*) were grown (intercropping was common), yielding a small but diverse harvest. Women reportedly applied compost (Fig. S-K) to their fields, especially on pepper plants. Yam and millet were considered to be labour intensive crops and their cultivation was reserved for men. With the responsibility of food provision lying with the male household head, women farmed with the objective of selling the majority of their crops. Generally, only the peppers, okra and groundnut were processed and partly consumed. The wives of the ‘Medium farmers’ (Type B) and ‘Big farmers’ (Type A) channelled income from crop sales into the purchase of personal items but the wives of ‘Smaller farmers (men)’ (Type C) forewent these luxuries in favour of investing in household necessities such as spices to supplement the food provided by household heads, and other basic necessities such as the education of their children. Most women also stored some of their produce in jute sacks and pots to sell for inputs (such as seeds) for the next season.

In all the communities, children were reported to be involved in agriculture. Boys learned how to farm on a small plot next to one of their father’s fields or out on their mother’s field if land was limited. Once adolescence was reached, boys were taken by their fathers to help out on bigger farms until they were married and could inherit land for themselves. Girls helped their mothers with all farm-related activities. Once married, girls were given a small plot by their husbands. Women and children accumulated as many as 10 small ruminants and some poultry, purchased with cash from crop sales. Fowls were sold for cash as needed. Especially boys were encouraged to sell their produce and invest in livestock, with which they could help secure a good marriage partner in the future. As a rule, women did not possess any cattle, nor did they keep guinea fowls, as these had a reputation for being too wild and unruly. Women did not belong to any major exchange labour networks but they hired 2-4 people per cropping season to help out on the farm as needed. In Tingoli it was reported that some women hired out tractor services for field preparation, but in the other communities the use of hoes and cutlasses was the norm. In addition to maintaining their own farms, women were responsible for helping with the planting, harvesting, threshing and winnowing duties on men’s farms, often as hired labour or in return for a part of the harvest. Furthermore, women were involved in a number of non-farming activities as part of their livelihood. These included shea butter extraction, processing and sale, small-scale food trading (Fig. S-G and S-H), firewood and charcoal collection for sale and household use, soap-making and processing of groundnuts into cakes and oil. Sales were made within the community and at local markets; held in six day cycles.

** Southern Ghana has two rainy seasons (first season from March-July and second season from August-November). Migrant youth from the North travel down south from February to May to sell their labour during the first season in the south and return back to the North to start their farming which starts in June (Marchetta 2011, 2013).
Type E. *Suhukpion* ('Farm-less, men'): work on other farms as hired labour

Described as ‘farmers who only farm for others for money but have no farm themselves’; this category was only identified in Tingoli and was considered to be the smallest, comprising a few men in the community (none of them were included in the survey). It was explained that Type E representatives were ‘farm-less’ by choice. Farming members of the community considered such men to be socially deviant as they voluntarily chose not to engage in cultivation of their own farms - the hallmark of a ‘true’ Dagomba man. They were labelled as ‘parasites’ with a ‘different aim from normal human beings’. Men of all ages could be found in this category. They generally remained unmarried, had no legitimate children and specialized in working as hired labour on other people’s farms within the community and beyond. Off-season they worked in masonry and construction or migrated to find work as seasonal labourers on farms in the South of Ghana. Considered to be ‘big spenders’, they did not own or accumulate any livestock, but instead used their wages on food and personal items of luxury. In many cases, however, they were sheltered and fed by the senior household head of the extended family within which they were embedded, and were known to borrow money when seasonal labour demand was scarce.
Fig. S (A) Women pounding boiled yams to make the staple food fufu; (B) A 'Big farmer' household head on his soybean (cash crop) farm; (C) A large, raised kambong (postharvest storage facility); (D) A pair of draught oxen; (E) Tractor outside a household compound; (F) Farmer-craftsman demonstrating how to make gabga rope; (G) Small-scale trading in dried okra at the local market; (H) Small-scale trading in yams at the local market; (I) Pepper harvest set out to dry before being stored for later sale/consumption; (J) Poultry flock of local chickens and guinea fowl; (K) Compost pit; (L) Maize harvest.

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