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Socioeconomic Aspects of Urban and Peri-urban Agriculture

A Diagnostic Study in Khartoum, Sudan

kassel university press

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This work has been accepted by the faculty of Organic Agricultural Sciences of the University of Kassel as a thesis for acquiring the academic degree of Doktor der Agrarwissenschaften (Dr. agr.).

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Dedication

To

The soul of my lovely mother

My sisters Inas, Sara, and Amani

Supporters of friends and relatives

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Summary

Socioeconomic Aspects of Urban and Peri-urban Agriculture: A Diagnostic Study in Khartoum, Sudan

Over the last decades, urban and peri-urban agriculture (UPA) have contributed to the efforts of humans to overcome poverty and food insecurity in many cities of the developing countries. Yet the main features, potentials, limitations, and consequences of UPA still vary, depending on location differences, and are debated worldwide. Each city is unique due to specificity of environment, climate, population preferences and main activities and space availability. However, little is known about UPA in Khartoum: practitioners, scale of production, resource use, and interaction with rural food production. This thesis aimed to explore the main socioeconomic features of urban farmers in Khartoum, Sudan, and to investigate into their links to farm performance, cash income, and income level. As well, the topic addressed other related activities such as vegetable markets and red brick making activity that compete with UPA for land use in Khartoum.

The study was conducted from July 2007 until April 2010. A total of 159 farmers (93 crop farmers and 66 dairy producers), who grow vegetables and forage crops in urban and peri-urban areas in 2007 were interviewed formally. From this pool of 159 farmers, 75 farmers (45 crop producers and 30 dairy farmers) were interviewed again in 2009 to trace changes in input use and farm cash income since 2007. Vegetables market prices for almost 20 crops in Shambat central market were monitored on a weekly basis for one year. Besides, 49 red brick kiln owners in urban areas were interviewed to detect out the return to land (rent value paid to land owner) and compare it with return to agricultural activity. Secondary data was also collected on vegetable prices and cultivated area from relevant sources. Descriptive, multivariate analyses, price trends, and generalized estimating equations (GEE) were used to pursue the stated objectives.

Many vegetable and forage crops are grown under variable cropping patterns. About 6%, 7%, and 86% of the total cultivated area were grown with leafy vegetable, other vegetables, and forage crops, respectively. Crop production and mixed production (crop and livestock) were practiced. Farmers trust their own experience, other farmers, and input-providing merchants as sources of agricultural information. Cluster analysis explained 96.6% of variance in the data set and resulted in four separate farmer groups according to the scale of production, namely small private farms, small mixed farms, medium mixed farms, and large mixed farms. The asset index depicted small values even for large farms, reflecting low accumulation of assets among farmers. Land, small cars, and big cars are most important assets owned by farmers. Kendall's

coefficient (*W*) indicated that food provision was the main priority for sampled farmers. Market availability and high consumption were the main incentives, whereas lack of government support, extension services and credit were the main disadvantages of UPA.

The farm size, cultivated area, cropping pattern, and animals owned showed variation during 2007 - 2009 at different levels that nevertheless did not vary significantly. Three fertilizer types, namely urea, foliar fertilizer and chicken manure were mentioned by farmers to be used in the study area. Urea price increased significantly by 50% between 2007 and 2009, encouraging some of the farmers to shift partly to chicken manure with lower proportional price increase. Measured by total livestock units (TLU), the number of livestock kept by sampled farmers increased while the average per farmer slightly decreased, most likely denoting an increase in livestock owners. Milk price significantly increased while milk sales decreased; though not significantly. Milk productivity slightly increased. Annual farm cash income increased, but not significantly. The contribution of livestock and crop sales to farm income varied between 2007 and 2009, which indicates flexibilities in managing income sources to increase benefits from the farm. The effect of some socioeconomic factors on farm income was tested using population-averaged (PA) models. Farm size, education, milk productivity, chicken manure, and forage area share were detected as significantly affecting farm cash income. Farmers' shift within different income strata was derived with income quartiles where farmers' status was found to change from one quartile to another. Farmers in the higher income group acquired a higher ratio of staying in their groups (50%) compared to those in the lowest income group (35%). The effect of socioeconomic factors on joining the higher income group was tested using logit function and binomial variance distribution. Farm size, off-farm income, family size, location (intra- and peri-urban), and education had significant effects. Location (intra- and peri-urban) showed a significant effect on the probability of joining higher income group and not on the amount of income per se.

The urban market is one determinant factor in UPA. The relation between traders and farmers play a great role in the flow of vegetable crops in Shambat central market either from Khartoum or from other regions of the country. Khartoum fully supplied the leafy vegetable types due to their perishability. Other vegetables came from different regions of Sudan, especially during the off-season when prices are high. Khartoum enjoys high self-sufficiency ratio in some vegetables ranging from 120%-167%. Average monthly wholesale prices for vegetables exhibited significant variations except for two crops. Average annual nominal and real consumer prices significantly varied for all tested crops except for onion's real price while monthly nominal and real consumer prices showed significant variations for some of the crops. For most crops, nominal and real consumer prices followed the same trend or movement pattern.

Red brick making (RB) is another activity that uses intra-urban land together with the agricultural production. The RB owners are educated males who depend on RB making as the sole source of income, where 14% of them have more than one kiln and most of them operated on rented land. Main inputs used in the RB are loose dung, which is used in mixture with clay and water, and compacted dung and wood which are used for brick burning. The prices of loose and compacted dung are changing during production season which extends for 10 months. The price of dung was low at the beginning of the season, increased when the price of red brick was high; then decreasing thereafter. Income inequality among urban farmers is higher than among red brick makers. The rent value for land is higher for RB making than for agriculture while the benefit cost ratio (B/C) for agricultural activity is higher than for RB making. This would mean that, through addressing the obstacles that hinder agricultural production in the study area, land owners will shift back to agricultural land use. Using loose and compacted dung manure as fertilizer will decrease fertilization cost in urban areas and improve farmers' income at the end. The output of dung and wood in the form of greenhouse gases were estimated to be 6% of the total country GHGs.

UPA Khartoum features with high variability and potentiality with regard to crop and livestock production. This could benefit food production in the study area if efficiency of resource use would be improved and hindrance of agricultural production would be addressed. The interaction with markets (inputs and outputs), rural crop production, and other economically competing activities would enhance the performance of this sector if tackled as one package in planning endeavours.

Zusammenfassung

Sozioökonomische Aspekte der urbanen und peri-urbanen Landwirtschaft: Eine explorative Studie in Khartoum, Sudan

In den letzten Jahrzehnten haben urbane und peri-urbane Landwirtschaft (UPL) in vielen Städten von Entwicklungsländern zu den Bemühungen des Menschen beigetragen, Armut und Ernährungssicherheit zu überwinden. Allerdings variieren die wichtigsten Merkmale, Potenziale, Grenzen und Konsequenzen der UPL in Abhängigkeit von regionalen Unterschieden und werden daher weltweit diskutiert. Jede Stadt ist einzigartig aufgrund der Spezifität von Umwelt- und Klimabedingungen, Vorlieben und Hauptaktivitäten der Bevölkerung sowie räumlicher Flächenverfügbarkeit. Indessen ist bisher wenig bekannt über einzelne Aspekte der UPL in Khartoum: Praktizierende, Umfang der Produktion, Nutzung von Ressourcen und die Interaktion mit Formen der ländlichen Lebensmittelproduktion. Ziel dieser Arbeit war es, wichtige sozioökonomischen Merkmale der städtischen Landwirte in Khartoum, Sudan, zu ermitteln. Dazu werden Leistungsmerkmale des landwirtschaftlichen Betriebs wie z.B. das Betriebseinkommen erfasst und eine Klassifikation der Höhe des Einkommens vorgenommen. Außerdem behandelt die Arbeit weitere damit in Zusammenhang stehende Aktivitäten wie den Handel mit Gemüse auf Märkten und die Herstellung von Ziegelsteinen, die mit der UPL um die Landnutzung in Khartoum konkurrieren.

Die Erhebungen wurden zwischen Juli 2007 und April 2010 durchgeführt. Insgesamt wurden 159 Landwirte (93 Ackerbauern und 66 Milchproduzenten), die Gemüse und Feldfutter in urbanen und peri-urbanen Gebieten im Jahr 2007 produzierten, formal befragt. Aus dem Pool dieser 159 Landwirte wurden 75 Landwirte (45 Ackerbauern und 30 Milchproduzenten) im Jahr 2009 erneut befragt, um Veränderungen beim Input von Betriebsmitteln und des Bruttoeinkommens im Vergleich zum Jahr 2007 feststellen zu können. Marktpreise für nahezu 20 verschiedene Gemüsekulturen wurden während eines Jahres in wöchentlichen Abständen auf dem Shambat Zentralmarkt beobachtet. Zusätzlich wurden 49 Besitzer von Rotziegel-Ziegeleien in städtischen Gebieten befragt, um die Rentabilität der Landnutzung (Wert der Pacht, die an den Landeigentümer bezahlt wird) zu ermitteln und sie mit der Rentabilität auf der Basis landwirtschaftlicher Nutzung zu vergleichen. Außerdem wurden Sekundärdaten zu Gemüsepreisen und der bewirtschafteten Landfläche aus einschlägigen Quellenangaben zusammengetragen. Um die genannten Ziele der Untersuchung zu erreichen, wurden sowohl deskriptive und multivariate Analysen als auch Generalized Estimation Equations (GEE) durchgeführt sowie Preisentwicklungen dargestellt.

Viele Gemüsekulturen und Futterpflanzen werden unter variablen Anbaustrukturen produziert. Blattgemüse wurde auf 6%, andere Gemüsekulturen auf 7 % und Futterpflanzen auf

86 % der gesamten landwirtschaftlichen Nutzfläche produziert. Betrieblich wurden Sowohl der reine Anbau von Feldfrüchten als auch eine Mischnutzung (Ackerbau und tierische Nutzung) praktiziert. Hinsichtlich ihrer Entscheidungsgrundlagen vertrauen Landwirte vor allem auf ihre eigene Erfahrung, aber auch die anderer Landwirte sowie den Händlern der benötigten Produktionsmittel. Die Cluster-Analyse konnte 96.6% der Variation des Datensatzes erklären, was eine Unterteilung in vier separate Gruppen von Landwirten entsprechend des Umfangs der Produktion nahe legte, nämlich in kleine Familienbetriebe, kleine Gemischtbetriebe, Gemischtbetriebe mittlerer Größe und große Gemischtbetriebe. Der Vermögensindex zeigte auch für die großen Betriebe nur geringe Werte auf, was eine generell niedrige Ansammlung von Vermögenswerten unter Landwirten wieder spiegelt. Landfläche sowie kleinere und große Fahrzeuge stellen die wichtigsten Vermögenswerte von Landbewirtschaftern dar. Der Kendall's-Koeffizient (*W*) deutete an, das die Bereitstellung von Lebensmitteln das Hauptanliegen der befragten Landwirte war. Eine gute Verfügbarkeit von Märkten und der hohe Verbrauch stellten die wichtigsten Anreize dar, während fehlende staatliche Unterstützung, Beratung und monetären Darlehen die wichtigsten Nachteile der UPL beinhalteten.

Betriebsgröße, Anbaufläche- und muster sowie Tierbestände variierten zwischen den Jahren 2007 und 2009 in unterschiedlichem Umfang, waren jedoch nicht signifikant verschieden voneinander. Drei Arten von Düngemitteln, Harnstoff, Blattdünger und Hühnermist, wurden laut den Aussagen der Landwirte in der Untersuchungsregion eingesetzt. Der Preis für Harnstoff hatte sich im Jahr 2009 deutlich um 50% im Vergleich zum Jahr 2007 erhöht. Dies führte dazu, dass einige der Landwirte teilweise auf Hühnermist, der einer niedrigeren proportionalen Preissteigerungsrate unterlag, zurückgriffen. Gemessen an den Großvieheinheiten (GVE) erhöhte sich die Anzahl der Nutztiere in der gesamten Stichprobe der befragten Landwirte, während sich der durchschnittliche Tierbesatz pro Landwirt verringerte, was höchstwahrscheinlich auf eine Zunahme von Nutztierhaltern zurückzuführen ist. Der Milchpreis stieg deutlich bei gleichzeitigem, nicht signifikantem Rückgang des Absatzes. Die produzierte Milchmenge erhöhte sich leicht. Das jährliche Bruttoeinkommen erhöhte sich, jedoch ebenfalls nicht signifikant. Der Einkommensbeitrag von Vieh- und Ackerfruchtverkäufen zeigte Unterschiede zwischen den Jahren 2007 und 2009 auf. Dies deutet auf ein flexibles Management der unterschiedlichen Einkommensquellen hin, um die Gesamterträge vom landwirtschaftlichen Betrieb zu erhöhen. Der Einfluss einiger sozioökonomischer Faktoren auf das Betriebseinkommen wurde anhand von Population-averaged (PA) models untersucht. Betriebsgröße, Bildung, Milcherträge, Hühnermist und Anteil der Futterfläche konnten als signifikante Einflussfaktoren auf die Entwicklung des Bruttoeinkommens identifiziert werden. Der Wechsel von Landwirten zwischen verschiedenen Einkommensschichten wurde von Einkommensquartilen abgeleitet; hier fanden Wechsel zwischen einzelnen Quartilen statt. Landwirte, die sich in der Gruppe mit höherem Einkommen befanden, erlangten einen höheren Quotienten, in ihrer Gruppe zu bleiben (50%), verglichen mit den Landwirten in der Gruppe mit

den niedrigsten Einkommen (35%). Die Auswirkung sozioökonomischer Faktoren auf den Wechsel in eine höhere Einkommensgruppe wurde mittels einer Logit-Funktion und einer binomialen Varianzverteilung getestet. Betriebsgröße, außerlandwirtschaftliches Einkommen, Familiengröße, Standort (intra- und peri-urban) sowie Bildung zeigten signifikante Effekte. Der Standort (intra- und peri-urban) zeigte überdies einen signifikanten Effekt bezüglich der Wahrscheinlichkeit, in eine höhere Einkommensgruppe zu wechseln, nicht aber bezüglich der Höhe des Einkommens per se.

Der urbane Markt ist ein bestimmenden Faktor der UPL. Die Beziehungen zwischen Händlern und Landwirten spielen eine große Rolle bei der Vermarktung von Gemüsekulturen aus Khartoum oder anderen Regionen des Landes auf dem Shambat Zentralmarkt. Vor allem Blattgemüse werden wegen ihre Verderblichkeit fast vollständig aus der UPA Khartoums geliefert. Andere Gemüsekulturen kamen aus verschiedenen Regionen des Sudan, gerade auch während der Nebensaison, wenn ein hohes Preisniveau vorherrscht. Khartoum zeichnet sich durch einen hohen Grad an Selbstversorgung bei einigen Gemüsearten aus, der sich zwischen 120% und 167% bewegt. Die durchschnittlichen Großhandelspreise für alle mit Ausnahme zweier Gemüsekulturen, unterlagen großen Schwankungen. Dagegen variierten die durchschnittlichen nominalen und realen Preise signifikant bei allen untersuchten Kulturen außer beim realen Preis für Zwiebeln. Die monatlichen nominalen und realen Preise zeigten signifikante Unterschiede bei einigen der Kulturen. Bei den meisten Kulturen folgten die nominalen und realen Preise dem gleichen Trend oder Entwicklungsmuster.

Die Herstellung roter Ziegel (RZ) stellt eine weitere Aktivität dar, bei der neben der landwirtschaftlichen Produktion die intra-urbane Landfläche genutzt wird. Die Eigentümer der Ziegeleien sind typischerweise ausgebildete Männer, die vollständig von der Herstellung roter Ziegel als einzige Einkommensquelle abhängen. 14% der Ziegeleibesitzer bewirtschaften mehr als einen Brennofen, die meisten bewirtschaften ihren Betrieb auf Pachtland. Als Hauptrohstoffe bei der Ziegelherstellung werden frischer Dung, der mit Lehm und Wasser vermischt wird, sowie getrockneter Dung und Holz, die zur Ziegelbrennung eingesetzt werden, genutzt. Die Preise frischen und getrockneten Dungs ändern sich während der Produktionssaison, die sich über zehn Monate hinweg zieht. Der Dungpreis war zu Beginn der Saison niedrig, erhöhte sich dann parallel zu den gestiegenen Ziegelpreisen, um danach wieder abzusinken. Einkommensunterschiede stellten sich als höher zwischen den urbanen Landwirten als zwischen den Ziegelproduzenten heraus. Die Bodenrente bei der Ziegelherstellung ist gegenüber der landwirtschaftlichen Nutzung höher, während das Kosten-Nutzen-Verhältnis für die landwirtschaftlichen Aktivitäten höher als für die Ziegelherstellung ist. Dies könnte bedeuten, dass die Beseitigung von Hindernissen für die landwirtschaftliche Produktion Landbesitzer dahingehend beeinflussen würde, dass Flächen wieder vermehrt für eine landwirtschaftliche Bodenproduktion zur Verfügung gestellt werden. Der verstärkte Einsatz von frischem und trockenem tierischem Mist als Düngemittel wird die Düngekosten in urbanen Regionen senken

und schlussendlich zu einer Einkommenssteigerung bei den Landwirten führen. Die Treibhausgasemissionen aus dem Einsatz von Mist und Holz wurden auf 6% des gesamten Treibhausgaspotenzials des Sudans geschätzt.

UPL in Khartoum zeichnet sich durch eine hohe Variabilität aus und birgt große Potenziale hinsichtlich der Pflanzen- und Tierproduktion. Davon könnte die Nahrungsmittelproduktion im Untersuchungsgebiet profitieren, wenn die Effizienz der Ressourcennutzung erhöht wird und die Benachteiligung der landwirtschaftlichen Produktion gebührend adressiert würde. Die Interaktion mit den Märkten (Inputs und Outputs), die Kulturpflanzenproduktion in ländlichen Gebieten und andere wirtschaftlich konkurrierende Aktivitäten würden die Leistungsfähigkeit dieses Sektors steigern, wenn sie zusammen als ein Paket in den Planungsbemühungen in Angriff genommen würden.

Chapter 1. General introduction, research objectives and hypotheses

1. General introduction

1.1. Urban agriculture

The high growth of urban areas and urban population is a worldwide phenomenon. PRAIN (2006) indicated that half of the world population is already living in urban centers while 1.5 billion people will be living in the cities by 2020. PARROT ET AL. (2010) mentioned that by 2030 about 50 percent or more of Africa population are expected to live in cities. The rapid urbanization has a great impact on food demand (BRYLD, 2003; MAXWELL, 1995) where the urban areas are showing high population growth (KING'ORI, 2004). BRYLD (2003) pointed to the growing importance of urban and peri-urban agriculture (UPA) in Africa where the engagement was increased from 10-25% of urban population in the beginning of 1980s to 70% in 1990s. UPA is always a source of food supply and income generation in the cities (BHATTA, 2010). The increase in migration from rural to urban areas, with agricultural background, and the rise in food prices are of the main drives why urban inhabitants seek to produce food for home consumption and to generate more income (BRYLD, 2003; MAXWELL, 1995; SIMATELE & BINNS, 2008). On the same level NITURAL (2006) determines the Urban and Peri-urban Agriculture (UPA) as a logical approach to easing problem of food scarcity in the populated centres. The importance of UPA as a community strategy and not only for food production was indicated by ASOMANI-BOATENG (2002) stating that "*Urban farming should not be viewed as a subsidiary and blighted activity on the urban landscape but rather as an important strategy for developing more productive, viable and sustainable urban habitats"*.

The unique location of Khartoum, Sudan's capital city at the confluence of the Blue and White Niles beside the rapid population growth due to migration from rural areas to the urban areas has led to rapid urban growth. The location at the bank of three rivers provides the fertile land and water (EL-KAROURI, 1979; ELTAYEB, 2003; SCHUMACHER ET AL., 2009). The urban growth in Sudan, as indicated by ELTAYEB (2003) is generally measured by increases in area and density more than by functional development. Most of the migrants from rural to urban regions are settled in peripheral areas. The percentage of those living in Khartoum suburbs and classified as rural has increased from 12% in 2007 to 19% in 2009 (CBS, 2009) indicating that the growth in the peri-urban area is higher than in intra-urban. This growth has supported and encouraged the expansion of the agricultural sector through crop and animal production. The expansion of these activities is of paramount importance to find out the main traits of this sector in Khartoum State. About 37 percent of total city area is potentially suitable for cultivation (KHARTOUM STATE MINISTRY OF AGRICULTURE, 2002) while only 11 percent of this area is cultivated. Khartoum harbours about 0.8 million heads of livestock (KHARTOUM STATE MINISTRY OF AGRICULTURE, 2002). As mentioned by ELTAYEB (2003), 4% of inhabitants are labourers in agriculture. SCHUMACHER ET AL. (2009) ascertained that, since 1958, agricultural area in Khartoum has been extended on the average by 172 ha per year, indicating that it is resource consuming and the main food supplier for the population living therein (EMAM, 2011). The rapid

expansion in the cultivated area is attracting rural farmers to join UPA as a source of continuous income.

1.2. Definition of UPA

Urban and peri-urban agriculture (UPA) has been defined by many researchers. ELLIS & SUMBERG (1998) stated that "*UA seems on first encounter to be just a convenient shorthand for describing food production activities taking place within and on the periphery of cities and towns*". This author referred to the idea that food production in cities is not the same as food production carried out elsewhere. HUNGWE (2006) defined urban agriculture as food production activity in the third world which increases due to the growth of urban poor population. On the other hand MOUGEOT (2000) focused on building a concept of UPA depending on internal coherence[1] (elements) and external functionality[2] (environment) to be able to identify the unique character of each city. He also mentioned the level of interaction and integration between both elements and environment and urban ecosystem to be an indicator for characterization of UPA (MOUGEOT, 2000).

Six dimensions were identified by MOUGEOT (2000) to build up the concept of urban agriculture. Those dimensions are types of economic activities (it is about production phase where processing and trade were added to investigation), food/non-food categories of products and sub-categories, intra-urban/ peri-urban character of location, types of areas where UPA is practiced, product destinations (consumption and/ or sale), and production systems (scale of) (Figure 1.1).

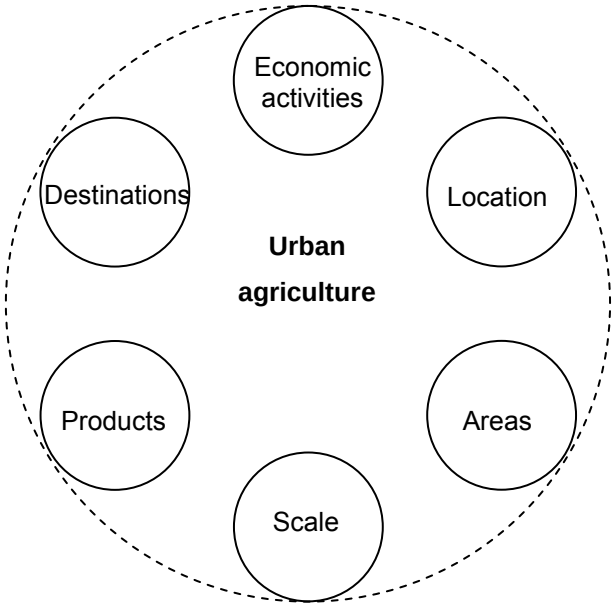

Figure 1.1. Urban Agriculture: Common Dimensions
(adapted From MOUGEOT, 2000)

[1] Is UA really what we call, or want to call, what we perceive to be out there?
[2] How does UA position itself relative to other "kids on the block" (e.g. rural agriculture, sustainable urban development, urban food supply systems, etc.)?

Different studies considered UA elements and dimensions to describe and characterize the UPA farming system worldwide. Usually researchers tackle more than one dimension which looks overlapping with each others. In Khartoum UPA was suggested to be defined as food and non-food production activities due to growth of urban population and availability of resources of land and water in intra- and peri-urban areas of the city (SCHUMACHER ET AL., 2009) in complementary role among both and with the rural cultivation. To well understand the UPA Khartoum, a number of issues were studied and focused on with a purpose to be able to give advice for well functioning of farmers and policy makers. The discussed issues are illustrated in Figure (1.1).

1.3. Main characteristics of UPA

Location, farm size, cropping pattern, production means, resources availability and uses, as well as household welfare are the criteria used for characterization of UPA (ASOMANI-BOATENG, 2002; CONKLINT, 1980; GRAEFE ET AL., 2008; MOUGEOT, 2000; THOMPSON ET AL., 2010; SAHN & STIFEL, 2003; SMIT ET AL., 1996). Location is the most common element used by researchers to identify intra- and peri-urban areas (MOUGEOT, 2000). Unavailability of land, mainly in intra-urban areas, is a great hindrance to UPA farming (DONGMO ET AL., 2005) as intensive land used is predominant (HOOVER & GIARRATANI, 1999). ADEDEJI & ADEMILUYI (2009) mentioned that UA in Lagos, Nigeria are practiced in unauthorized farms. Some farmers use home-plots to cultivate perishable vegetables or raise poultry. In general urban agriculture is known to be associated with high-input/output production (DIOGO ET AL., 2011). Crop intensification is practised in UPA (ADEDEJI & ADEMILUYI, 2009; DIOGO ET AL., 2011; MAWOIS ET AL., 2011). A piece of land is cultivated more than once a year especially with leafy vegetable crops and mostly with excessive use of inputs as fertilizers, pesticides and raw organic matter (DIOGO ET AL., 2011; MAWOIS ET AL., 2011). MAWOIS ET AL. (2011) indicated that the land allocation among the crops inside the farm depends on several decision variables. Among them are the maximal exploitable surface area, cultivable area of each crop (for example when a crop is water demanding, it is cultivated near water source, or the plot size is changed when water shortage is faced), and duration of each crop as farmers decide on the duration due to economic reasons (such as a change in market price), and variation in climate.

PRAIN (2006) stated that "*in Sub-Saharan Africa, urban and peri-urban horticultural and livestock systems also supply large volumes of urban needs"*. Different studies indicated the importance of UPA to enhance food security for urban inhabitants through cultivation of loose and perishable and relatively high-valued vegetables besides production of animal products and byproducts (ADEDEJI & ADEMILUYI, 2009; DIOGO, 2009; DONGMO, 2005; GOCKOWSKI, 2003; HUNGWE, 2006; MOUGEOT, 2000; SIEGMUND-SCHULTZE & RISCHKOWSKY, 2001; SIMATELE & BINNS, 2008; SMIT ET AL., 1996). Intra-urban areas are dominated by perishable leafy vegetables grown with high crop intensity due to the short duration of crop (MAWOIS ET AL.,

2011). It is encouraged by the near markets and high demand and possibility to produce short life and perishable products (HOOVER & GIARRATANI, 1999). PRAIN (2006) and DONGMO ET AL. (2005) reflected on the importance of indigenous leafy vegetables that are grown in the peri-urban areas of Yaounde in Cameroon and consumed by poor urbanites in the city, and fresh cassava which is bulky and costly in transportation for food security. The labour demanding crops as lettuce and other long cycle crops such as onion or cabbage are rather not grown in the intra-urban areas in Mahajanga, Madagascar (MAWOIS ET AL., 2011). Peri-urban agriculture is also important for the supply of perishable vegetables to the urban areas (MOUSTIER, 2007) in complementarity with rural and foreign sources of food supply to cities (BHATTA, 2010; MOUGEOT, 2000).

The increasing demand for livestock products lead to widespread raising of animals in urban areas (DIOGO, 2009; THOMPSON ET AL., 2010). In the region of Sub-Saharan West Africa DIOGO (2009) concluded the importance of livestock as source of food, income and employment, saving and as insurance system. Livestock raised in urban areas included goats, sheep, and cows (DIOGO, 2009; GRAPHAE ET AL., 2008). SIEGMUND-SCHULTZE & RISCHKOWSKY (2001) tried to identify the underlying reasons and characteristics that are predispose to urban livestock keeping, which could be a consequence of poverty regardless of the origin and cultural background of the people. MOUGEOT (2000) referred to the non-food production as part of the UA concept, which corroborated the findings of SMIT ET AL. (1996). Khartoum harbours about 204,354 cows, 617,000 goats, 424,000 sheep, and 30,468 horses and donkeys (Khartoum State Ministry of Agriculture, 2002).

Migration is increasing from rural to urban areas (BRYLD, 2003; MAXWELL, 1995). Due to difficulties to get an employment and the need for self subsistence, the migrants join agricultural work (MOUGEOT, 2000).The migrants were being attracted by UPA especially the poor migrants with agrarian background. The migrants work as farmers or labours in the agricultural schemes or private farms. ADEDEJI & ADEMILUYI (2009) indicated that UA farmers in Lagos, Nigeria, are mainly Hausa (one of the main tribes in Lagos) or migrant farmers who cannot secure alternative job within the city.

1.4. Farm cash income in urban and peri-urban area

With regard to UA dimensions it was noted that UA practitioners are either food and/or income seekers. Urban and peri-urban agriculture (UPA) support urban households through improving food supply and enhance household income (ADEDEJI & ADEMILUYI, 2009; DIOGO ET AL., 2011; THOMPSON ET AL., 2010). UPA can provide access to supplementary income for some people and it is the sole source of income for others. DONGMO ET AL. (2005) regarded UPA as a source of employment and incomes through crop cultivation and livestock raising. MOUGEOT (2000) stated that "*UA is comparatively affordable, a noteworthy source of income and savings and is more profitable than rural-based production*". HUNGWE (2006) mentioned the importance

of UPA as being a survival strategy for poor people. The broad diversity of horticultural crop species grown in many areas allows year-round production, employment and income (ADEDEJI & ADEMILUYI, 2009). The production of leafy vegetables provides a quick return that helps families to meet their daily cash requirements for purchasing other food (ADEDEJI & ADEMILUYI, 2009).

Farm income in urban areas is affected by different factors as farm size, animal resources, crops grown, fertilizer used, technology adopted, labour, input and output markets, age and experience on farming activity (BÄCKMAN & SUMELIUS, 2009; DIOGO ET AL., 2011; DRECHSEL ET AL., 2004; EDMONDS, 1999; NDAMBI & HEMME, 2009; POON & WEERSINK, 2011; SHARMA ET AL., 2007; URASSA & RAPHAEL, 2002; ZHANG-LIN & YING, 2010). Generally farm income is highly sensitive to changes in inputs used, inputs prices, outputs produced and output prices (DIOGO, 2009; DRECHSEL ET AL., 2004; URASSA & RAPHAEL, 2002). In the urban farms, dealing with sensitive, perishable, and high-value products, changes are expected to be highly reflected on the farm performance. ELRASHEED & AWAD (2009) indicated the possibility of getting negative farm income when potato farmers in Khartoum sell at harvest time.

Socioeconomic factors and economies of scale affect the farm cash income (PHIMISTER ET AL., 2004; POON & WEERSINK, 2011; SHARMA ET AL., 2007). POON & WEERSINK (2011) indicated that location, farm size, farm type are sources of variability where specialization increases income volatility mainly for crop farms in comparison to livestock farms. Farm income volatility encourages farmers to resort to off-farm employment and income. Off-farm income is one of the factors affecting farm income, through provision of inputs and financial support for farm work (POON & WEERSINK, 2011). Its contribution and impact on the household varies from one community to another depending on whether it will be used to support the agricultural work or being spent on food and other consumable items (BABATUNDE & QAIM, 2010). POON & WEERSINK (2011) explained that the possibility to have time for off-farm employment varied among crop, grain and oilseed, and livestock producers. The same author also indicated the importance of off-farm income as enhancing household income and making food more accessible.

Using the first four waves of the British Household Panel Survey (1991-1994) JARVIS & JERKINS *(*1998) observed that the mobility of household income from one year to the next where the income changes are not very large in Great Britain. PHIMISTER ET AL. (2004) studied the effect of farm characteristics on exit and re-entry rate from and to low income group among Canadian farmers. They indicated that farm characteristics as farm size, type, tenure, region and farmer's age have effects on shifts in income distribution*;* in other words moving out of or into low income group*.* PHIMISTER ET AL. (2004) findings indicated that farm size has positive response on cash income and older farmers are likely to stay in the low income group. Age effect on income is also mentioned by JARVIS & JERKINS (1998) where elderly people have instable income.

1.5. Role of vegetable market in UPA

SMIT ET AL. (1996) stated that "*UPA refers to food and fuel grown within a city or peri-urban area, and produced directly for market and /or household use*". The urban areas are large local markets for crop and animal products. This was confirmed by PRAIN (2006) mentioning that urbanization includes an enormous expansion in markets for agricultural products, especially for livestock products, high value horticultural crops, and processed products. This author also indicated that UPA supply large volumes of urban needs of horticultural and animal products. Khartoum is known as the main producer and consumer region of vegetables in Sudan (ELRASHEED & AWAD, 2009; EMAM, 2011). This market attracts production from urban and rural areas. One of the main incentives for UPA growth is its adaptability and mobility compared with rural agriculture (ADEDEJI & ADEMILUYI, 2009) being near to the markets and consumers. Urban farmers have comparative advantage over rural farmers in the supply of these products within a short time because of their proximity to the various locations for consumptions (ADEDEJI & ADEMILUYI, 2009). This is also indicating that the urban area is a market for rural producers where part of rural products is consumed by urban residents (MOUGEOT, 2000; NITURAL, 2006). The urban market is a target for rural producers who are desperately looking for extra profit (NITURAL, 2006). The UPA provide higher prices than local rural market for rural producers which encourage them to produce the crops favoured by UPA consumers. Urban farmers diversify crops as responding to wholesalers and consumers demands or in reflection for market prices (MAWOIS ET AL., 2011). Changes in vegetable prices within the year and from year to year in Khartoum were indicated by ELRASHEED & AWAD (2009) and EMAM (2011).

A few farmers sell their crops by themselves while the largest share is being sold through the wholesale traders as in Mahajanga, Madagascar (MAWOIS ET AL., 2011). Crops are mostly harvested by the buyers (MAWOIS ET AL., 2011).

Low consumption of vegetables in developing countries in comparison to the international recommendation, 400 g capita^{-1} day^{-1}, put pressure on production to enhance the nutrition of inhabitants (WHO, 2003). In Sudan, vegetable consumption stands at 112 g capita^{-1} day^{-1} (FAO, 2010). A set of factors affect vegetables prices as well as their consumption. Supply and demand, seasonality, climates, input prices, crop lag price, access to credit, and crop characteristics and shelf life are affecting market prices of vegetables and their fluctuations (BÄCKMAN & SUMELIUS, 2009; CASAVANT ET AL., 1999; DOGONDAJI, 2007; FONASH, 2003; GREIG, 2009; KOMAREK, 2010; SHONKWILER, 1982). Inflation is also another factor affecting the price of vegetable crops (USAID, 2009). Inflation is the general rise in price level (CASAVANT ET AL., 1999) where such relative changes in prices affect production and consumption (REARDON ET AL., 1997). Input use and production are also affected due to these changes (REARDON ET AL., 1997). CASAVANT ET AL. (1999) indicated that indices are most commonly used for price analysis. The price index allows for relative comparison for a single commodity or between items overtime. One of the common indices is the Consumer Price Index (CPI) which measures

the changes in prices of goods and services bought by families or wage earners (CASAVANT ET AL., 1999). The market price is called nominal price and the price used to calculate the CPI is called real price (USAID, 2009).

1.6. Land use in UPA

HUNGWE (2006) mentioned that UPA competes for resources with other land use activities as housing and industrial development (HOOVER & GIARRATANI, 1999). ADEDEJI & ADEMILUYI (2009) stated that "*Population pressure not only directly increases the demand for food, but also indirectly reduces its supply through building development, environmental degradation and marginalization of food production*". MOUGEOT (2000) indicated that access to land is the issue rather than availability which encourages the diversification of production system to cope with this problem. Thence farmers resort to access land through sharing, lease, and through cooperative societies, rather than land ownership. Also they resort to use small fragmented lands to overcome the unavailability of land (DONGMO ET AL., 2005). In Lagos, Nigeria, the land ownership system makes it rather cumbersome for poor urban farmers to access land (ADEDEJI & ADEMILUYI, 2009). In most cases the area available for farming is small so the farmers grow small plots where available. SMIT ET AL. (1996) also mentioned different technologies and practices to overcome the availability of small areas in the UPA areas as: hydroponics, aeroponics, container farming and bio-intensive gardening. The higher costs of acquiring land make it difficult for poor farmers to get into the business. Where also other activities are bidding agriculture in intra-urban areas, the value of land use is high (HOOVER & GIARRATANI, 1999). For example red brick production is practiced near highly populated areas while agricultural activities moved to areas far from the city (SINGH & SARFARAZ ASGHER, 2005).

SMIT ET AL. (1996) indicated that UA farming systems have different demands for urban space. So far the urban farming is practiced where land is vacant, either not suitable for building or is awaiting development, rather than that land is suitable for farming in particular. Due to the high value of intra-urban land, agriculture is forced out of the central areas of cities to more peripheral locations (SIMATELE & BINNS, 2008; SINGH & SARFARAZ ASGHER, 2005). Small and fragmented lands are cultivated in UPA, especially in the intra-urban areas, except in the case of cooperatives. Unavailability of land is a great hindrance to collective areas (DONGMO ET AL., 2005). So intensive land used is predominant in UPA. A piece of land is cultivated more than once a year especially with leafy vegetable crops and large amount of inputs are used (DIOGO ET AL., 2011; MAWOIS ET AL., 2011).

1.7. Research methods employed in UPA research

Different topics were discussed in UPA research studies. Those topics cover the characterization and main themes of UPA beside the consequences and constraints related to practicing agriculture in urban areas using local resources. The characterization and definition

of UA demands investigation of different elements and environments at the study area. The Socioeconomic factors are part of the elements that affect UPA. To capture those elements different methods were used. Observation and repeated visits for quite enough time during the season was adopted in many studies (ABDU, 2010; DIOGO, 2009; SAFI, 2011). Different stakeholders were defined and farmers, crop growers and livestock keepers, traders, and different stakeholders were considered due to the objective of the study. Primary and secondary data were collected and used in the analysis (ABDU, 2010; DIOGO, 2009; EMAM, 2011; MOUSTIER, 2007; SAFI, 2011). A review of a set of studies was also used by SMIT ET AL., (1996). Structured and semi-structured questionnaires, informal interviews, and informal group discussion were used (ASOMANI-BOATENG, 2002; BHATTA, 2010; GRAEFE ET AL., 2008; THOMPSON ET AL., 2010; SAHN & STIFEL, 2003). Descriptive analysis as means, standard deviations and graphs is used (ASOMANI-BOATENG, 2002; DIOGO, 2009; GRAEFE ET AL., 2008; THOMPSON ET AL., 2010). Statistical analysis as parametric and non-parametric analysis was also used as well as regression and modeling (BHATTA & NEUPANE, 2010). Multivariate technique is used to understand the situation in the study area, decision making, farming systems, and socioeconomic characteristics of UPA farmers (BHATTA, 2010; BERNHOLDT ET AL., 2009; THOMPSON ET AL., 2010). Spatial analysis is also used in studying urban agriculture (BHATTA, 2010; MAWOIS ET AL., 2011; SCHUMACHER ET AL., 2009). It is employed to identify the location of urban farms in the city and the cropping pattern (BHATTA, 2010; MAWOIS ET AL., 2011; SCHUMACHER ET AL., 2009).

The classification of UPA farmers using multivariate analysis was implemented in many studies (BERNHOLDT ET AL., 2009; THOMPSON ET AL., 2010). Using cluster in grouping of respondents is used in different studies to distinguish between sheep keepers and non-keepers (SIEGMUND-SCHULTZE & RISCHKOWSKY, 2001), plant species richness and diversity (BERNHOLDT ET AL., 2009; THOMPSON ET AL., 2010). Yet, case-driven cluster may not allow distinguishing totally between groups (SIEGMUND-SCHULTZE & RISCHKOWSKY, 2001). This, as SIEGMUND-SCHULTZE & RISCHKOWSKY (2001) indicates, give information about the variability and potentiality of moving from one group to another.

Shannon index and Global Positioning System (GIS) were used to study biodiversity in UPA and maps were produced (DIOGO, 2009; SAFI, 2011; SCHUMACHER ET AL., 2009; THOMPSON ET AL., 2010). Spatial analysis and modelling are used to study resources use, assessment of Socioeconomic conditions, and future requirements and planning (BHATTA, 2010; SCHUMACHER ET AL., 2009). BHATTA & DOPPLER (2010) and BHATTA & NEUPANE (2010) used spatial analysis and modelling to simulate farming differentiation in the rural-urban interface and farming income.

With regard to household welfare, asset index was considered as appropriate indicator to measure household wellbeing because of difficulties in collecting reliable data on household income and expenditures (FEULEFACK ET AL., 2006; FILMER & PRITCHETT, 1998; SAHN & STIFEL,

2003). Detailed budget for crops was implemented in many studies (DIOGO, 2009; SAFI, 2011) to investigate the profitability and resource uses in UPA Niamey, Niger and Kabul, Afghanistan. Local and improved resources are investigated as well as efficiency of vegetable production (DIOGO, 2009; SAFI, 2011). Livestock production was also investigated in Niamey, Niger (GRAEFE ET AL., 2008; DIOGO, 2009).

ADEDEJI & ADEMILUYI (2009) referred to the use of recycled treated waste water as the most viable source of water for UA in Lagos, Nigeria. Consequences of using wastes as waste water and animal manure was investigated and the availability and impacts of heavy metals on vegetables and human health was studied in Sikasso, Mali; Bobo-Dioulasso, Burkina Faso; Kano, Nigeria (ABDU, 2010). On the other hand also horizontal and vertical nutrients flows and their ecological consequences in Kabul, Afghanistan were investigated (ABDU, 2010; DIOGO, 2009; SAFI, 2011). Issues as food supply and potential contribution of UPA in urban food supply was investigated in Africa and Asia (MOUSTIER, 2007). Self-sufficiency and complementary role of intra-, peri-urban and rural areas was studied with consideration to sources and supply of food crops in Africa and Asia (MOUSTIER, 2007).

In Khartoum different studies were implemented with regard to agricultural activities. Some studies looked after slums and poor people (ELTYEB, 2003) while others looked after crop production and markets of tomato and potato (ELRASHEED & AWAD, 2009; ELTOUM, 2008; EMAM, 2011). On the other hand forages were studied (Mohammed & Mohamed, 2009). Other researchers studied the effect of organic fertilizer and treated sewage water on yield and quality of forage crops (ABUSUWAR & EL ZILAL, 2010; ELSHEIKH ET AL., 2006; TAHA ET AL., 2002; YOUSIF & MUBARAK, 2009).

1.8. Research objectives

The overall objective of this study is to characterize the urban farming in Khartoum city in terms of assets, opportunities, and constraints and to determine the socioeconomic conditions of the farmers and their impact on UPA farming. So a set of objectives were specified as follows.

1. To identify and characterize the main socioeconomic features of the UPA farms in Khartoum. This classification helps the extensionists and policy makers to detect the needs, priorities, and provide support for the farmers' groups.
2. To explore changes in socioeconomic factors, resources and resource use that relate to the farming activities between two production years and their impact on farm cash income.
3. To identify different sources for vegetables flow to the urban market and describe the relationship between traders and vegetable producers inside and outside Khartoum, beside the investigation of the trend in vegetable wholesales and consumer prices, in order to identify the potentiality of vegetable markets in Khartoum.

4. To identify the aspects of red brick production as a competing activity with urban agriculture in using land in intra-urban settings, and to identify incentives, profitability, and consequences on environment, of this activity.

This dissertation is organised in six chapters. The first chapter was the introductory part. From the second to the fifth are fully written papers in a purpose to be published. Only fifth chapter was written with others and submitted to a referee journal. In this fifth part I write the economic part under supervision of Prof. Dr. Detlev Moeller and Sahar Babiker Abdalla write the part related to natural science under supervision of Prof. Dr. Andreas Buerkert and Prof. Dr. Kamal El-Siddig. Furthermore a chapter of conclusion and discussion was written at the end where also some recommendations were formulated.

1.9. Research hypotheses

For the sake of this study we hypothesised that:

1. Urban farmers are having different resources, financially, naturally, and human which lead to variability in production scales and benefits.
2. Urban farmers are adapting to the climate and socioeconomic changes in the urban setup where the inputs used and farm cash income are affected.
3. Urban market is attractive for vegetable products from inside and outside urban areas which encourage their flow; benefiting from seasonality and significantly changing prices.
4. Being a limited resource with higher value, intra-urban land could be used for agriculture or other more profitable activities.

1.10. Analytical framework

Figure 1.2 represents the analytical framework employed in this study. Collected data includes two types, primary and secondary data. Primary data collected using semi-structured questionnaires where the interviewees belong to three groups: farmers in urban and peri-urban area, wholesale vegetable traders in Shambat central market, and red brick kiln owners. Farmers were interviewed in 2007 and again in 2009. The wholesale vegetable traders were visited weekly from February 2009 to January 2010 to collect wholesale price for a set of vegetable crops. The third group, red brick kiln owners, were interviewed in 2009. Secondary data on vegetable consumer prices, vegetable cultivated areas in Khartoum and Sudan, and consumption of some vegetable crops were collected from relevant sources as Central Bureau Statistics; Directorates, Agricultural Ministry; and relevant publications.

Descriptive, econometrics, and multivariate analyses were adopted to answers the research questions raised for the sake of this study. Results were discussed and a set of recommendations were suggested.

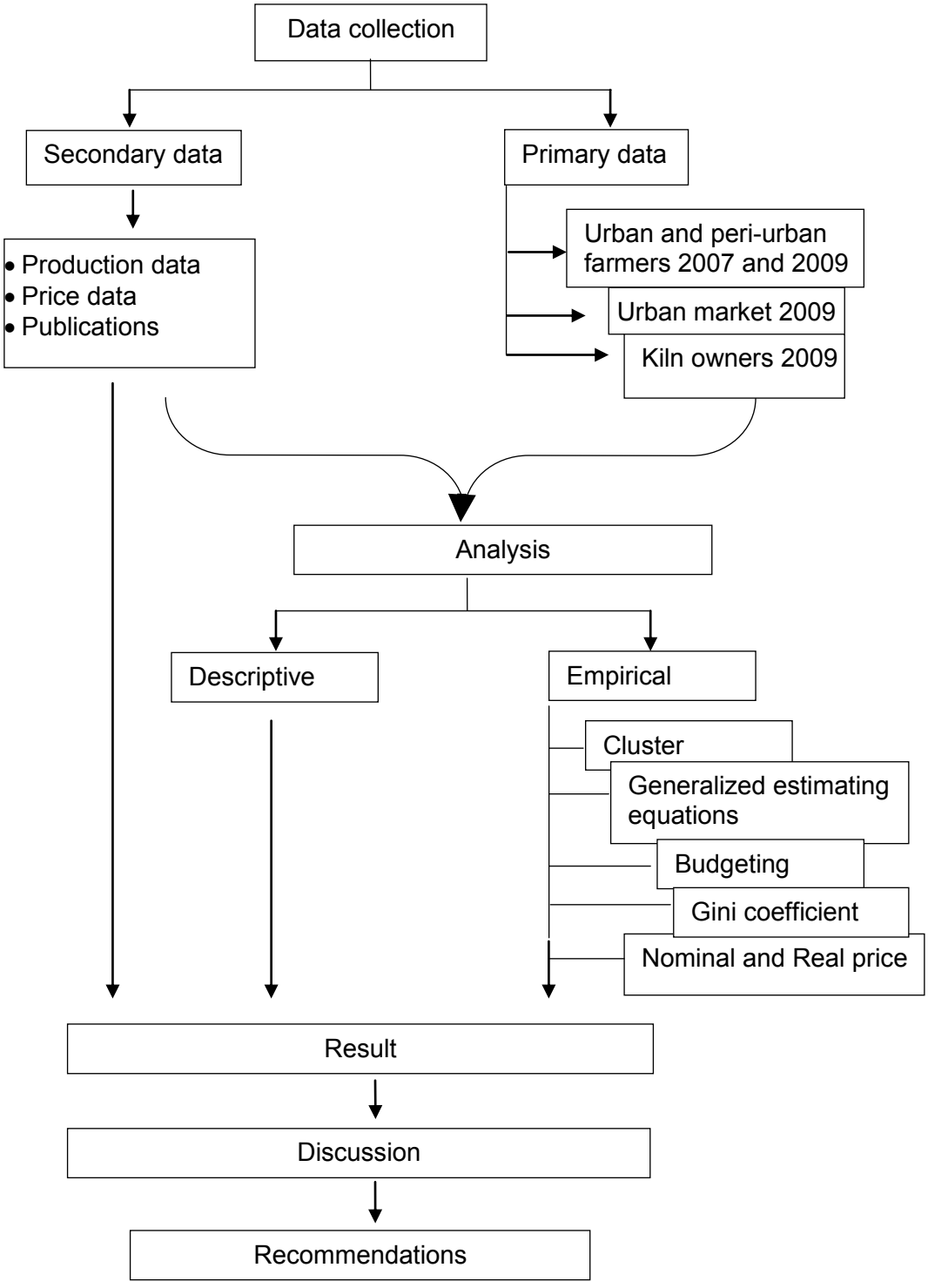

Figure 1.2. Analytical framework.

Own illustration.

1.11. References

ABDU, N. (2010): Availability, transfer and balances of heavy metals in urban agriculture of West Africa. Dissertation presented to the Faculty of Organic Agricultural Sciences/ Group Animal Husbandry in the Tropics and Subtropics University of Kassel.

ABUSUWAR, A. O. and EL ZILAL, H. A. (2010): Effect of chicken manure on yield, quality and HCN concentration of two forage Sorghum (*Sorghum bicolor* (L) Moench) cultivars. Agriculture and Biology Journal of North America 1(1): 27-31.

ADEDEJI, O. H. and ADEMILUYI, I. A. (2009): Urban agriculture and urban land use planning: Need for a synthesis in metropolitan Lagos, Nigeria. Journal of Geography and Regional Planning 2(3): 043-050.

ASOMANI-BOATENG, R. (2002): Urban cultivation in Accra: an examination of the nature, practices, problems, potentials and urban planning implications. Habitat International 26: 591–607.

BABATUNDE, R. O. and QAIM, M. (2010): Impact of off-farm income on food security and nutrition in Nigeria. Food Policy 35: 303-311.

BÄCKMAN, S. and SUMELIUS, J. (2009): Identifying the driving forces behind price fluctuations and potential food crisis. Discussion Papers No35, Department of Economics and Management, University of Helsinki. Available at: http://www.mm.helsinki.fi/mmtal/abs/ DP35.pdf. Accessed 23 June 2010.

BERNHOLT, H., KEHLENBECK, K., GEBAUER, J. and BUERKERT, A. (2009): Plant species richness and diversity in urban and peri-urban gardens Niamey, Niger. Agroforestry Systems 77(3): 159-179.

BHATTA, G. D. (2010): Socio-economic and spatial assessment of smallholder peri-urban farming in the middle mountains of Nepal. Margraf publishers GmbH.

BHATTA, G. D. and DOPPLER, W. (2010): Farming differentiation in the rural-urban interface of the Middle Mountains, Nepal: application of Analytic Hierarchy Process (AHP) Modeling. Journal of Agricultural Science 2(4): 37-51.

BHATTA, G. D. and NEUPANE, N. (2010): Simulating farm income under the current soil management regime in the mid-hills of Nepal. Himalayan Journal of Sciences 6(8): 27-34.

BRYLD, E. (2003): Potentials, problems, and policy implications for urban agriculture in developing countries. Agricultural and Human Values 20: 79-86.

CASAVANT, K. L., INFANGER, C. L. and BRIDGES, D. E. (1999): Agricultural economics and management. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

CBS (CENTRAL BUREAU OF STATISTICS) (2009): Statistical year book for the year 2009. Ministry of the Cabinet, Government of the Republic of the Sudan, Khartoum.

CONKLINT, H. E. (1980): Preserving agriculture in an urban region northeast regional research project 90 report. New York's Food and Life Science bulletin No 86.

DIOGO, R. V. C. (2009): Horizontal nutrient fluxes and production efficiencies in urban and peri-urban crop and livestock husbandry of Niamey, Niger. Dissertation presented to the Faculty of Organic Agricultural Sciences/ Group Animal Husbandry in the Tropics and Subtropics University of Kassel.

DIOGO, R. V. C., BUERKERT, A. and SCHLECHT, E. (2011): Economic benefit to gardeners and retailers from cultivating and marketing vegetables in Niamey, Niger. Outlook on Agriculture 40(1): 71–78.

DOGONDAJI, S. D., BABA, K. M. and MOHAMMED, I. (2007): Profitability and resource use efficiency in dry season onion production in Sokoto and Kebbi states, Nigeria. International Journal of Agriculture and Rural Development 9: 35-39.

DONGMO, T., GOCKOWSKI, J., HERNANDEZ, S., AWONO, L. D. K. and MOUDON, M. À. (2005): Peri-urban agriculture in Yaounde: its relation to poverty alleviation, economic development, biodiversity conservation and the environment. Tropicultura 23(3): 130-135.

DRECHSEL, P., GIORDANO, M. and GYIELE, L. (2004): Valuing nutrients in soil and water concepts and techniques with examples from IWMI studies in the developing world. International Water Management Institute, Research report 82.

EDMONDS, C. M. (1999): The effect of technology transfer program participation on small farms in Chile. Selected paper for presentation at the Annual Meeting of the American Agricultural Economics Association, August 8-11, 1999, in Nashville, Tennessee.

EL-KAROURI, M. O. H. (1979): Effect of soil salinity on the productivity of arid lands, with special reference to the Sudan. In: MABBUTT, J. A. (Ed.): Proceedings of the Khartoum workshop on arid lands management. The United Nations University.

Ellis, F. and Sumberg, J. (1998): Food production, urban areas and policy responses. World Development 26(2): 213-225.

ELRASHEED, M. M. M. and AWAD, F. H. B. (2009): Economics of potato production and marketing in Khartoum State. Journal of Science and Technology 10(2): 80-91.

ELSHEIKH, E. A.E., ELNESAIRY, N. N. B. and MAHDI, A. A. (2006): Effect of *Sinorhizobium* Inoculation and chicken manure on nodulation and forage yield of Alfalfa (*Medicago sativa* L.) under irrigation in a semi-arid environment. University of Khartoum Journal of Agricultural Sciences 14(2): 182–197.

ELTAYEB, G. E. (2003): The case study of Khartoum, Sudan. In: Understanding slums: case studies for the global report on human settlements 2003. Available at: http://www.ucl.ac.uk/dpu-projects/Global_Report/pdfs/khartoum_bw.pdf. Accessed 30 May 2010.

ELTOUM, Y. A. A. (2008): Evaluation of the factors affecting the production and marketing of tomato crop in Khartoum State, Sudan. Unpublished thesis submitted for Ph. D degree, Department of Agricultural Economics, University of Khartoum.

EMAM, A. A. (2011): Evaluating marketing efficiency of tomato in Khartoum State, Sudan. Journal of Agriculture and Social Sciences 7: 21-24.

FAO (2010): Food consumption. Available at: http://www.fao.org/economic/ess/food-security-statistics/en/ Accessed 6 Jan. 2011.

FEULEFACK, J. F., ZELLER, M. and SCHWARZE, S. (2006): Accuracy analysis of Participatory Wealth Ranking (PWR) in Socio-economic poverty comparisons. Discussion paper No. 44. Department of Agricultural Economics and Rural Development, Socioeconomics of Rural Development, University of Goettingen, ISSN 1433-2868.

FILMER, D. and PRITCHETT, L. (1998): Estimating wealth effects without expenditure data -- or tears: with an application to educational enrollments in states of India. Policy research working paper No. 1994, The World Bank.

GOCKOWSKI, J., MBAZO'O, J., MBAH, G. and MOULENDE, T. F. (2003): African traditional leafy vegetables and the urban and peri-urban poor. Food Policy 28: 221–235.

GRAEFE, S., SCHLECHT, E. and BUERKERT, A. (2008): Opportunities and challenges of urban and peri-urban agriculture in Niamey, Niger. Outlook on Agriculture 37(1): 47-56.

GREIG, L. (2009): An analysis of the factors influencing farmer's choice of crop, Kibamba Ward, Tanzania. Journal of Agricultural Economics 60(3): 699-715.

HOOVER, E. M. and GIARRATANI, F. (1999): An introduction to regional economics. Third edition © 1999, Regional Research Institute, WVU.

HUNGWE, C. (2006): Urban agriculture as a survival strategy: an analysis of the activities of Bulawayo and Gweru urban farmers (Zimbabwe). Published by city farmer, Canada's Office of Urban Agriculture. Available at: http://www.cityfarmer.org/ZimbabweSecurity.html Accessed 11 Oct. 2010.

JARVIS, S. and JERKINS, S. P. (1998): How much income mobility is there in Britain?. The Economic Journal 108: 428-443.

KHARTOUM STATE MINISTRY OF AGRICULTURE (2002): Overview of agriculture in Khartoum State. Unpublished report in Arabic.

KING'ORI, P. (2004): Assessment of urban and peri-urban agriculture research in the Centres of the Consultative Group on International Agricultural Research (CGIAR) in Sub-Saharan Africa. Urban harvest series, paper No. 1 © Urban Harvest, 2004, ISSN 1811-1440.

KOMAREK, A. M. (2010): Crop diversification decisions: the case of vanilla in Uganda. Quarterly Journal of International Agriculture 49(3): 227-242.

MAWOIS, M., AUBRY, C. and BAIL, M. L. (2011): Can farmers extend their cultivation areas in urban agriculture? A contribution from agronomic analysis of market gardening systems around Mahajanga (Madagascar). Land Use Policy 28: 434–445.

MAXWELL, D. G. (1995): Alternative food security strategy: A household analysis of urban agriculture in Kampala. World Development 23(10) pp: 1669-1681.

MOHAMMED, M. I. and MOHAMED, M. A. (2009): Evaluation of newly developed Sweet Sorghum (Sorghum bicolour) genotypes for some forage attributes. American-Eurasian Journal of Agricultural and Environmental Sciences 6(4): 434-440.

MOUGEOT, L. J. A. (2000): Urban agriculture: definition, presence, potentials and risks, and policy challenges. In: BAKKER, N., DUBBELING, M., GUENDEL, S., SABEL KOSCHELLA, U. and DE ZEEUW, H. (Eds.): Growing cities, growing food, urban agriculture on the policy agenda. DSE, Feldafing, pp 1-42.

MOUSTIER, P. (2007): Urban horticulture in Africa and Asia, an efficient corner food supplier. Acta Horticulture 762: 145-148.

NDAMBI, O. A. and HEMME, T. (2009): An economic comparison of typical dairy farming systems in South Africa, Morocco, Uganda and Cameron. Tropical Animal Health and Production 41: 979-994.

NITURAL, P. S. (2006): Urban agriculture program in the Philippines: Its beginning and status. a paper presented in the workshop titled urban/peri-urban agriculture in the Asian and Pacific region, and held in Tagaytay City, Philippines, 22-26 May 2006, available at: http://www.agnet.org/activities/sw/2006/729863362/. Accessed 11Oct. 2010.

PARROT, L., PEDELAHORE, P., DE BON, H. and KAHANE, R. (2010): Urban and peri urban horticulture and the capability approach, the case of the south-west province of Cameroon. Innovation et Development Durable (ISDA), Montpellier 28-30 June 2010.

PHIMISTER, E., ROBERTS, D. and GILBERT, A. (2004): The dynamics of farm incomes: panel data analysis using the Farm Accounts Survey. Journal of Agricultural Economics 55(2): 197-220.

POON, K. and WEERSINK, A. (2011): Factors affecting variability in farm and off-farm income. Structure and Performance of Agriculture and Agri-products Industry Network, working paper #2011-3.

PRAIN, G. (2006): Urban harvest: A CGIAR global program on urban and peri-urban agriculture. a paper presented in the workshop titled urban/peri-urban agriculture in the Asian and Pacific region, and held in Tagaytay City, Philippines, 22-26 May 2006. available at: http://www.agnet.org/activities/sw/2006/729863362/. Accessed 11Oct. 2010.

REARDON, T., KELLY, V., CRAWFORD, E., DIAGANA, B., DIONE, J., SAVADOGO, K. and BOUGHTON, D. (1997): Promoting sustainable intensification and productivity growth in Sahel agriculture after macroeconomic policy reform. Food Policy 22(4): 317-327.

SAFI, Z. (2011): Nutrient cycling and nutrient use efficiency in urban and peri-urban agriculture of Kabul/ Afghanistan. Dissertation presented to the Faculty of Organic Agricultural Sciences/ Group Animal Husbandry in the Tropics and Subtropics University of Kassel.

SAHN, D. E. and STIFEL, D. C. (2003): Urban-Rural Inequality in Living Standards in Africa. Journal of African Economies 12(4): 564-597.

SCHUMACHER, J., LUEDELING, E., GEBAUER, J., SAIED, A., EL-SIDDIG, K. and BUERKERT, A. (2009): Spatial expansion and water requirements of urban agriculture in Khartoum, Sudan. Journal of Arid Environments 73: 399–406.

SHARMA, Y. K., BANGARVA, G. S. and SHARMA, S. K. (2007): Factors affecting gross and net income of farmers in different farming systems. Indian Research Journal of Extension Education 7(1): 51-56.

SHONKWILER, J. S. (1982): An empirical comparison of agricultural supply response mechanisms. Applied Economics 14: 183-194.

SIEGMUND-SCHULTZE, M. and RISCHKOWSKY, B. (2001): Relating household characteristics to urban sheep keeping in West Africa. Agricultural Systems 67: 139-152.

SIMATELE, D. M. and BINNS, T. (2008): Motivation and marginalization in African urban agriculture: The case of Lusaka, Zambia. Urban Forum 19: 1–21.

SINGH, A. L. and SARFARAZ ASGHER, M. (2005): Impact of brick kilns on land use/landcover changes around Aligarh city, India. Habitat International 29: 591–602.

SMIT, J., RATTA, A. and BEMSTEIN, J. (1996): Urban agriculture: An opportunity for environmentally sustainable development in Sub-Saharan Africa. Towards Environmentally Sustainable Development in Sub-Saharan Africa, Environmentally Sustainable Division, Africa Technical Department (AFTES), The World Bank.

TAHA, I. M., HAMZA, N. B. and MALIK, M. N. (2002): Utilization of treated water for forage production. Proceedings of International Symposium on Environmental Pollution Control and Waste Management, 7-10 January 2002, Tunis (EPCOWM 2002): 560-572.

THOMPSON, J., GEBAUER, J., HAMMER, K. and BUERKERT, A. (2010): The structure of urban and peri-urban gardens in Khartoum, Sudan. Genetic Resources Crop Evolution 57: 487–500.

URASSA, J. K. and RAPHAEL, E. (2002): The contribution of small scale dairy farming to community welfare: A case study of Morogoro municipality. Electronic publications from Sokoine University of Agriculture, Morogoro, Tanzania, available at: http://www.fiuc.org/esap/MOROG/MOROG5/General/dairyfarming.pdf. Accessed 15 May 2011.

USAID (2009): Adjusting prices for inflation and creating price indices. FEWS NET Markets Guidance, No 3, available at: http://www.fews.net/docs/Publications/ MTGuidance_Price Adjustment for Inflation_No3_En.pdf. Accessed 7 May 2010.

WHO (2003): Diet, nutrition and the prevention of chronic diseases. WHO technical report series; 916, Report of a Joint WHO/FAO Expert Consultation Geneva.

YOUSIF, A. M. and MUBARAK, A. R. (2009): Variation in nitrogen mineralization from different manures in semi-arid tropics of Sudan with reference to salt-affected soils. International journal of Agriculture and Biology 11(5): 515-520.

ZHANG-LIN, X. and YING, N. (2010): Factors affecting the income of farmers. Asian Agricultural Research 5(2): 18-20.

Chapter 2. Socioeconomic characteristics of urban and peri-urban agriculture in Khartoum, Sudan

Abstract

The unique location of Khartoum State combined with rapid population growth provides an excellent opportunity for the expansion of agriculture within (Intra-urban) and surrounding (peri-urban) the boundaries of the state. The importance of intra-urban and peri-urban agriculture (UPA) is to provide fresh vegetables and livestock production to the population and to benefit from unused resources. The objective of the present study was to characterize the main features of the production systems and to analyse the livelihood patterns of the selected farming groups with respect to their physical, natural, financial, human and social assets. A sample survey of 159 farmers was conducted in the Intra- and peri-urban areas covering different aspects of plant and animal production. Cluster analysis, factor analysis, and descriptive analysis was used. Results indicated that the UPA farmers have a low level of accumulation of assets in general. Four farmer groups were generated using some criteria that describe the level and nature of production, namely farm size, cultivated areas, off-farm income, experience in agricultural work (years), cultivated crops, consumed urea kg farm^{-1} year^{-1}, and other factors. The grouping was more towards production scale instead of products and location. The farmers groups show significant differences in relation to the explored criteria. Farming is the main occupation for about 85 percent of the sampled farmers. Some of them come from rural and agrarian areas to work as farmers.

Forage crops are dominating in the peri-urban areas, where farmers show better level of education, higher family size, and long experience in practicing agricultural activities. Leafy and other vegetables are dominant in the Intra-urban where most of the farmers are non-native and have the lowest average age. Most farmers depend on their own experiences or observe their neighbours to obtain information, while only a few of them seeks formal extension services. The major constraints to the development of UPA were related to environmental and health risks, scarcity of land and lack of government support.

Keywords: urban farms, socioeconomic factors, cluster analysis

2.1. Introduction

The higher growth of urban areas and urban population is evident worldwide. Half of the world population is already urban (PRAIN, 2006). UNDP mentioned that about 800 million urban residents were engaged in agricultural production for subsistence and commercial purposes in the mid 1990s (BRYLD, 2003). In Africa, by 2030 about 50 percent or more of population is expected to live in cities (PARROT, 2010). The population engagement in urban agriculture (UA) in Africa increased from 10-25% in the beginning of 1980s to 70% in 1990s (BRYLD, 2003).

Khartoum, Sudan capital city, accounts for 13.5% of the country's population (CBS, 2009). The unique location of Khartoum and the rapid growth of the population, due to migration from rural areas to the urban center, have supported and encouraged the growth of the agricultural sector through plant and animal production. The expansion of these activities is of paramount importance to find out the main traits of this sector in Khartoum State. SCHUMACHER ET AL. (2009) mentioned that, since 1972, agricultural area in Khartoum has been extended on the average by 129 ha $year^{-1}$, indicating that it is resource consuming and an important food supplier for the population living there in. The rapid expansion in the cultivated area is attracting rural farmers to join urban and peri-urban agriculture (UPA) as a source of income.

Defining UPA as the production of food within the cities and its periphery areas was the common understanding among researchers when start dealing with UPA issues (ELLIS & SUMBERG, 1998). Then it was known that UPA is not as food production that carried elsewhere, as in rural areas. From this point MOUGEUT (2000) indicated the uniqueness of each city due to the element and environment of the city. Furthermore this author gave a complete definition stating that "*UA is an industry located within (intra-urban) or on the fringe (peri-urban) of a town, a city or a metropolis, which grows or raises, processes and distributes a diversity of food and non-food products, (re-)using largely human and material resources, products and services found in and around that urban area, and in turn supplying human and material resources, products and services largely to that urban area"*.

In Urban agriculture different elements were pointed out by researchers to describe and characterize the UPA farming systems worldwide. Location, farm size, cropping pattern, production means, resources availability and uses, as well as household welfare are the criterion used for characterization (ASOMANI-BOATENG, 2002; BRYLD, 2003; GRAEFE, 2004, GRAEFE ET AL, 2008; MOUGEOT, 2000; SAHN ET AL., 2003; SMIT ET AL., 1996; THOMPSON ET AL., 2010). Asset index was considered as appropriate indicator to measure household well being because of difficulties while collecting reliable data on household income and expenditures (FEULEFACK ET AL., 2006; FILMER ET AL., 1998; SAHN ET AL., 2003).

The rapid urbanization has a great impact on food demand (MAXWELL, 1995; BRYLD, 2003) where the urban areas showing high population growth (BRYLD, 2003). The importance of UPA as a strategy was reflected by MAXWELL (1995) and NITURAL (2006) as a survival strategy for easing problems of food security among household in the populated centers. ASOMANI-BOATENG

(2002) indicated UPA as a community strategy and stated that "*Urban farming should not be viewed as a subsidiary and blighted activity on the urban landscape but rather as an important strategy for developing more productive, viable and sustainable urban habitats"*.

It was indicated by many researchers the importance of UPA for food supply and income generation through cultivation of fresh vegetables and bulky and costly one (DONGMO ET AL., 2005; GOCKOWSKI, 2003; HUNGWE, 2006; SCHUMACHER ET AL., 2009; SMIT ET AL., 1996). PRAIN (2006) determined UPA as supplier of large volumes of urban needs especially horticultural and livestock products especially for poor urbanites in the capital Younde, Cameroon. DONGMO ET AL. (2005) related to UPA as source of employment and incomes through crop cultivation and livestock raising.

To identify the UPA aspects in Khartoum, two hypotheses were tested. Firstly the social and economic traits related to the agricultural practitioners in the study area are similar and/or homogeneous. Secondly the UPA encourage the variability as vegetable, forage and, animal products where practitioners are determined as commercial producers and income seekers.

The main objective of this study is to identify and characterize the main socioeconomic features of the UPA farms in Khartoum. Social and economic aspects of practitioners were identified where natural, financial, and human resources were looked after. UPA practitioners were classified and grouped with similar socioeconomic characteristics. Such classification is important for relevant stakeholders to be able to identify and provide relevant needs that can serve and develop the agricultural sector in the study area and add to the food providence efforts.

2.2. Materials and Methods

2.2.1. Site description

Khartoum State (15° 40' N, 32° 30' E, 382 m a.s.l.) is characterized by a semi desert climate, with an annual average rainfall of 155 mm (THOMPSON ET AL., 2010) and monthly average temperature fluctuates around 28.7° C and ranges between 19.6° and 33.6° C (Weather station data[1], 2007). The mean annual rainfall recorded in 2007 was 127 mm.

Khartoum State constitutes three governorates, Khartoum, Khartoum North, and Omdurman. The bulk of the cultivated area is located in Khartoum North (Khartoum Bahry), with about 51% in comparison to Khartoum and Omdurman governorates during 2006 (THOMPSON ET AL., 2010; KHARTOUM STATE MINISTRY OF AGRICULTURE AND FORESTRY, 2006).

Two areas were identified for comprehensive representation of population of the study area, Intra[2]- and peri-urban areas. The intra-urban areas were defined as the agricultural areas

[1] A device used to collect weather data and located in the study area mainly for UPA project, urban and peri-urban location.

[2] The definition of Intra and peri-urban depend on the distance from living area, and Khartoum witnessed a great expansions of living around the city.

around the River Nile near the conjunction point of the Blue and White Niles. The peri-urban areas expand in the areas relatively far from the city center. Crop cultivation and animal raising are practiced in this area. The existence of mixed production system "crop-livestock" was obvious where forage crops dominate in the production systems.

2.2.2. Sample and data collection

A household survey was conducted during July to September 2007. Primary data was collected for season 2006/07 from the 159 sampled farmers who practice agricultural activities in the intra- and peri-urban locations under three subsystems: private, cooperative, and public. Crop producers and mixed producers (crop and livestock) were interviewed. The sampled farmers were selected randomly under each subgroup. Two main categories were identified: intra-urban, where all respondents are crop producers, and peri-urban which comprises two main groups or producers: a) crop growers and b) mixed crop livestock producers. About 23 percent of sampled farmers were located in intra-urban area while 77 percent were peri-urban farmers. The peri-urban were divided into two groups: crop producers, 46 percent, and others, 54 percent, practicing mixed crop-livestock production system (Figure 2.1).

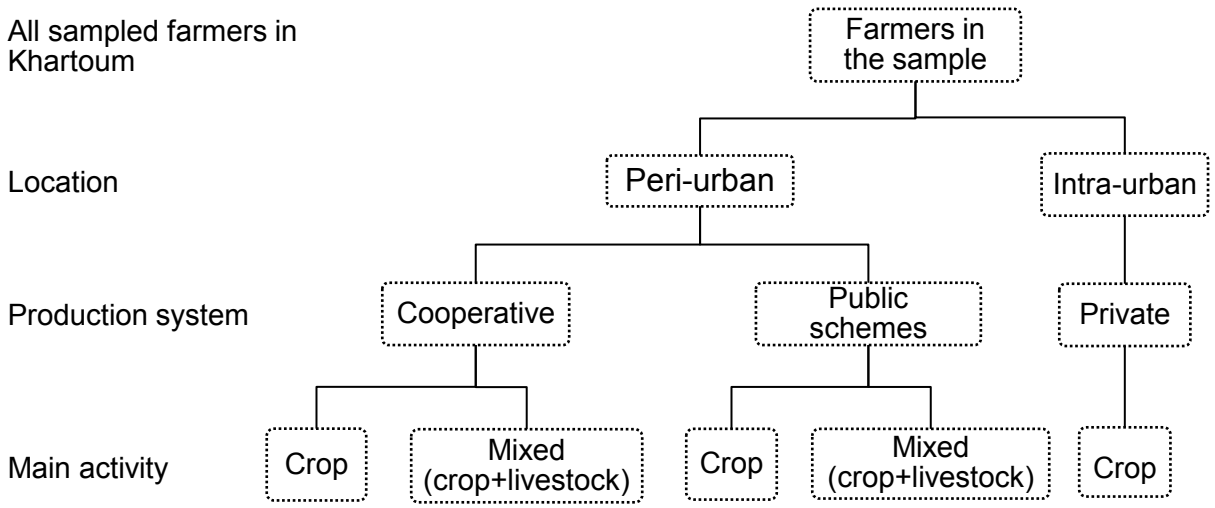

Figure 2.1. Distribution of the sampled farmers in the study area among location and production systems.

Primary data was collected using semi-structured questionnaire targeting different information as: land utilization, cultivated crops, inputs used, output, and general information about the sources of finance if used, sources of information and farmers point of view about UPA, advantages and disadvantages of UPA.

Figure 2.2 shows the location of the surveyed and sampled farms during 2007 (Google Earth map of Khartoum, Sudan).

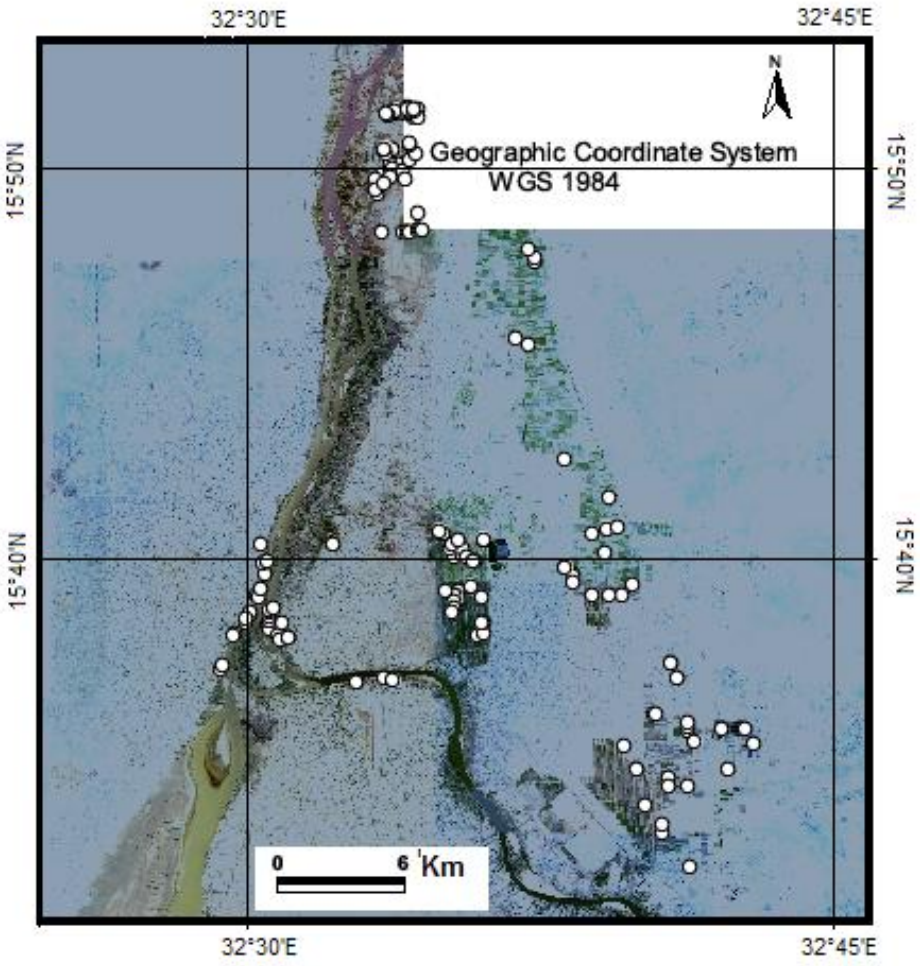

Figure 2.2. Google Earth Pro image of Khartoum, Sudan, 2006. The white dots indicate the locations of the 140 sampled farms surveyed in different locations in the intra- and peri-urban sites in Khartoum North, Khartoum, and Omdurman of Khartoum state in 2007.

2.2.3. Data analysis

Multivariate statistical analysis (MVSA) (MCGARIGAL ET AL., 2000) was used to identify the main socioeconomic aspects of the urban agriculture. The farms were classified and grouped into four groups based on non-location characteristics that included variables relating to structure, function, management, and household dynamics. Hierarchical cluster analysis was carried out using squared Euclidean distances and the 'ward's method' which is known as 'minimum variance' method (MCGRAIL ET AL., 2000). To define the correct number of different clusters, the 'elbow' criterion and dendogram were used (ROVAN & SAMBT, 2003; STOCKBURGER, 1998).

Crop cultivation and animal production were the main distinctive or characteristic variables used to differentiate between the two groups: urban and peri-urban producers. Farm size, area under shared system, number of cows, off-farm income, area cultivated by leafy vegetable (ha), total area of forage crops (%), total annual cultivated area (%), number of crops, and experience of practicing agricultural activities (years) were the variables used for classification. Land

preparation methods (animal vs. tractor), labour (family vs. wage), origins (Khartoum vs. outside), marketing (selling in the market vs. selling in the farm), asset index, and annual consumed amounts of urea fertilizer were added to the categorical criterion for more distinction among groups.

Pairwise ranking exercises were conducted on a list of predetermined priorities (food providence, wealth accumulation, resource use, and others) for practicing agricultural activities by respondents in the study area. Farmers were asked to rank the priorities for practicing agricultural activities from 1 to 4. Only few had other reasons for practicing agriculture; and was therefore removed from the analysis. The strength of agreement between individuals was assessed using Kendall's coefficient of concordance (*W*). *W* ranges from 0 to 1 with the higher values indicating a stronger relationship.

Factor analysis was used to generate the asset index, according to the procedure described by several authors (FEULEFACK ET AL., 2006; FILMER & PRITCHETT, 1998). Using the Kaiser criterion, principal components (PC) were extracted from the data and rotated using varimax rotation (LEECH ET AL., 2005). The first factor was requested to design the most important assets that were accumulated for farmers. Only variables with extraction value higher than 0.3 were included in the calculation of the factor value (LEECH ET AL., 2005; SPSS Inc., 2004). Thence saved the value of first factor for individuals and then standardized and converted to the ranges (0–100) which were used as a variable in the cluster analysis.

To explain the differences among the groups generated using cluster analysis discriminant analysis was applied; also to identify the most discriminating variables as defined through the standardized canonical discriminant function coefficients (MCGARIGAL ET AL., 2000; STOCKBURGER, 1998).

2.3 Results

To get an idea about the study area some basic information as total land, the cultivated crops, production systems, and origin of respondents were investigated. The survey covered a total farming area of about 659 ha, where 6, 7, and 86 percent of land was covered by leafy vegetables, other vegetables, and forage crops, respectively (Table 2.1). Also the survey recorded about 2175, 295, and 292 cows, goats and sheep, respectively. Crop intensification is employed in the study area where land is on average cultivated more than 2 times annually (Table 2.1).

The sampled farmers were distributed among the main production systems that were found in Khartoum city: private (23%), cooperatives (39%), and public schemes (38%) which mainly differ in their land ownership and irrigation regime. Farmers in the private system acquire land either through ownership, rent, or share cropping while among the other farming systems, farmers are either land owners or renters and few of them are resorting to shared system especially in vegetable production.

The farming system is attracting non-native farmers from rural areas and they are increasing during the last few years. Only 44% have source of finance; mainly available for those belonging to cooperatives or through shared relationships.

Table 2.1. Land utilization (ha) among sampled farmers (n=159) in Khartoum, 2007.

Items	% of farmers	Min	Max	Total	Mean	% of Total area
Total area	100.0	0.20	37.8	658.9	4.1	
Total cultivated area	100.0	0.20	110.0	1483.4	9.4	225
Leafy vegetable area	19.5	0.10	8.8	91.3	3.0	6
Other vegetable area	37.1	0.20	21.8	107.6	1.8	7
Forage area	83.0	0.03	110.9	1282.2	9.7	86

Source: Field survey, 2007.

2.3.1. Cropping pattern

According to Table 2.2, farmers are working during the three seasons (summer, winter and autumn) actively different where the cropping pattern for UPA farmers includes the production of leafy vegetables, other vegetables and forage crops. Summer and winter are the most active seasons especially for intra-urban farmers. Jew's mallow, rocket cress, and purslane are the most cultivated leafy vegetables in the intra-urban areas while forage crops, especially sorghum forage and *Zea maize* dominated in the peri-urban areas. Both vegetables and forage farms shows variability in the cropping pattern in UPA (Figure 2.3).

Table 2.2. Cropping pattern, % farmers and area (ha) for the sampled farmers (n=159) for the summer, winter and autumn seasons in Khartoum, 2007.

Crop	Summer season		Winter season		Autumn season	
	% farmers	Mean area (ha)	% farmers	Mean area (ha)	% farmers	Mean area (ha)
Jew's mallow	13.8	0.4	5.6	0.2	3.8	0.2
Rocket cress	15.0	0.3	12.0	0.4	5.0	0.6
Purslane	11.3	0.3	10.0	0.2	1.3	0.3
Onion	3.8	0.8	13.0	0.8		
Tomato			6.9	0.9	2.5	0.4
Egg plant	5.6	0.5	5.6	0.3	3.1	0.8
Okra	1.3	3.3	1.3	5.4	0.6	1.3
Cucumber	1.3	1.3	3.1	0.8	2.5	0.9
Chard	1.9	0.3	1.3	0.2	0.6	0.4
Vigna unguiculata	1.9	0.3	1.3	0.2	0.6	0.2
Radish	1.9	0.4	5.6	0.3		
Faba bean			3.1	0.5		
Sorghum forage	80.0	5.0	24.0	6.7	20.0	29.2
Alfalfa	6.9	0.9	14.0	0.8	1.3	2.5
Zea maize	1.9	0.5	35.6	4.2		

Source: Field survey, 2007.

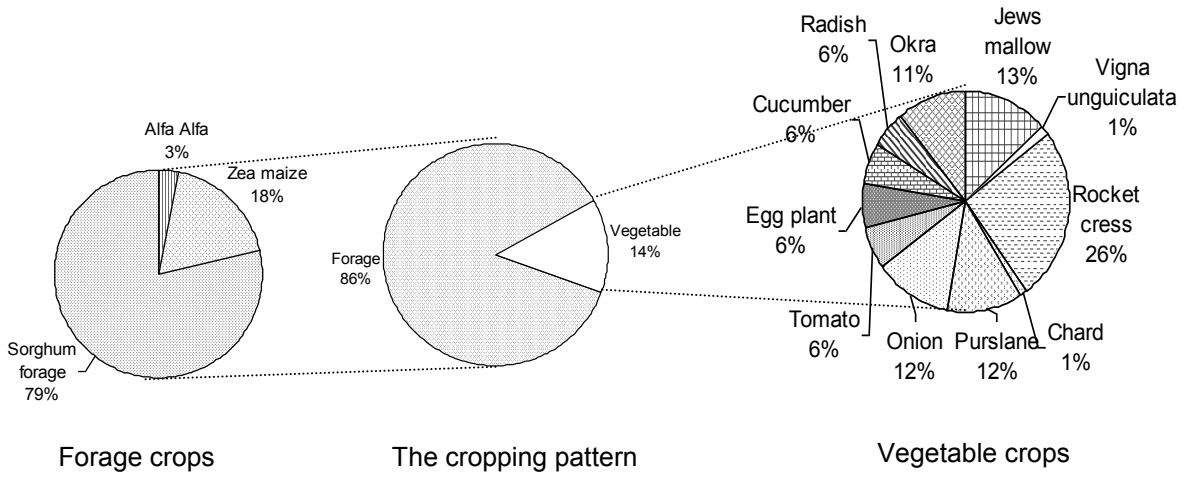

Figure 2.3. Cropping pattern: cultivated crops area (%) of vegetables and forages for the sampled farmers (n=159) in Khartoum, 2007.

2.3.2. Extension services

Figure 2.4 shows that farmers incline to depend on their own experience or on neighbouring farmers more than on formal extension services as source of agricultural information. Also farmers mentioned input-supplying merchants as a source of information regarding types and uses of fertilizers, seeds, and pesticides. The non-native farmers in intra- and peri-urban centers are usually coming with their knowledge and experience from their own

living areas in spite of practicing different crops in different ecosystems. Peri-urban farmers under cooperatives or public schemes may make use of the extension service provided by the cooperative and public schemes especially when the inputs are provided by the management.

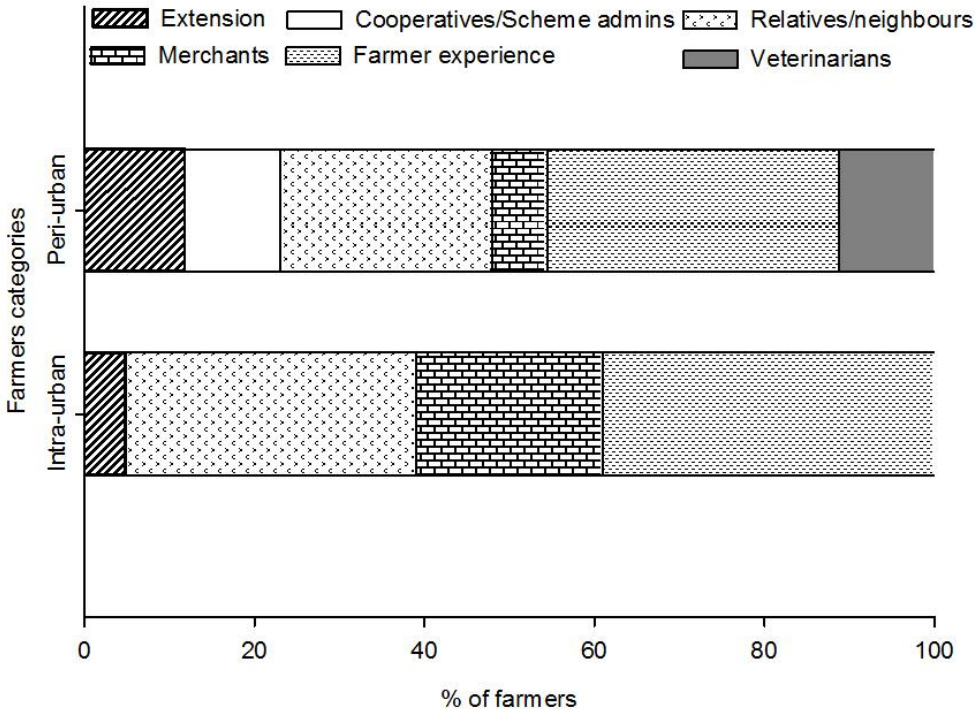

Figure 2.4. Percentages of information sources for intra- and peri-urban farmers in Khartoum, 2007.

Sample size = 159

Intra-urban (n) = 36 Peri-urban (n) = 123

Number of answers = 41 Number of answers = 169

2.3.3. Factor analysis for farmer's assets

The first factor was generated, by using asset variables, to be one of the variables set that were used in the cluster analysis to define farmers groups in the study area. The variables with extraction value more than 0.3 were chosen in the calculation of the factor value (Table 2.3).

Table 2.3 shows that most of the farmers' assets were loaded in the first factor with KMO = 0.65, indicating that this factor has relatively enough items (variables) for prediction, and Bartlett's test was highly significant at 99% level of confidence (p=0.000), with factor 1 explains 36.6% of variance or variability.

Table 2.3. Factor loadings and communalities for the factors.

Asset Items	Estimated Factor Loadings	Communalities (Extraction)
Land	0.742	0.551
Small cars	0.681	0.463
Big cars	0.666	0.443
Houses value	0.652	0.425
Others	0.650	0.423
Tractors	0.619	0.383
Lorry	0.477	0.228
Eigenvalues	2.928	
% of variance	36.6	

Extraction Method: Principal Component Analysis.
Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO)[3] = 0.65
Bartlett's Test of Sphericity = .000

2.3.4. Cluster Analysis

Using the Elbow criterion and dendogram, four groups were determined (Table 2.4) as most suitable groups to represent the sampled farmers in the study area and identified as follows: private and small crop producers (PSCP), medium mixed producers (MMP), large mixed producers (LMP) and the small mixed producers (SMP). The first canonical discriminant function explained 84% of the variance while the second canonical discriminant function explained 12.6% of the variance.

The selected criteria produced significant differences among groups (Table 2.4), and the result shows that about 96.9% of originally grouped cases were correctly classified. The classified groups show that the PSCP produce leafy vegetable, use animals in land preparation with low off-farm income, have higher level of crop diversification and intensification beside the intensive use of urea and lower level of assets. The MMP are native, with relatively medium off-farm income and inclination to cultivate forage crops. The LMP has lowest off-farm income, a few numbers of crops, mainly forage, with low level of assets but comparatively highest than other groups. SMP has the highest off-farm income and higher experience in agricultural activities.

Table 2.4 shows that the PSCP on average employs diverse and intensive cultivation. Most of the farmers in the PSCP are non-native farmers and some of them depend on sharecropping to support the farming activity which is their main source of income. In comparison, the LMP group seems to have better accumulation of livelihood means (assets), in comparison to other groups, because they have more than one source of income, crop and animal production, which may explain the higher level of asset index. In general the analysis showed that most of the farmers has low asset index.

[3] KMO scores of 0.60 are acceptable, above 0.70 are good, above 0.80 are comparable and above 0.90 are exceptional (NYAGA, 2009)

Table 2.4. Mean and standard deviations or percentage for cluster analysis groups of the sampled farmers (n=159) in Khartoum, 2007.

Variables	Private & small crop producers (PSCP) (n= 40)		Medium mixed producers (MMP) (n=60)		Large mixed producers (LMP) (n= 35)		Small mixed producers (SMP) (n= 24)	
	Mean (%)	Std dev.	Mean (%)	Std dev.	Mean (%)	Std dev.	Mean (%)	Std dev.
Farm size (ha)	2.13	2.46	4.33	6.63	7.63	7.96	1.83	2.79
Area under share system (ha)	0.83	0.96	0.08	0.33	0.14	0.54	0.01	0.04
Native farmers (1= Native, 0 = non-native)	5		98		0		100	
Cows no	0.3	1.3	16	29.8	37	69.8	4.5	15.4
Family labor (1= family labor, 0= wage labor)	43		0		0		100	
Mechanization (1= tractor,0= animal)	75		100		100		100	
Off farm income %	12	22.2	20	28.6	11	24.5	26	34.2
Number of crops farm^{-1} year^{-1}	3.9	2.1	2.5	1.3	2.2	1.0	2	1.0
Market access(1= selling in the market, 0= selling in the farm)	78		40		0		42	
Total forage area %	60	95.2	145	100.5	195	112.1	132	79.3
Cultivated area %	317	199.3	195	115.2	249	125.7	205	160.5
Leaf vegetable area (ha)	1.9	2.3	0.2	1.2	0.03	0.2	0.1	0.47
Experience in Agric. (Year)	20	12.1	28	16.7	17	14.4	27	19.3
Urea (kg farm^{-1} year^{-1})	1218	1329.5	1882	3614.0	3507	3628.5	892	1549.9
Assets Index	1.4	2.0	5.5	7.6	10.7	18.2	5.5	11.7

Source: Field survey, 2007.

PSCP and LMP groups are constitutes of non-native farmers with low off-farm income compared with the MMP and SMP groups. This is demonstrated by the separation of the cases in function 1 along the x-axis, while function 2 on the y-axis displays the separation according to the strongest influencing variable of family labour (Figure 2.5). The scattered diagram (Figure 2.5) shows that the groups were well separated by the selected criteria.

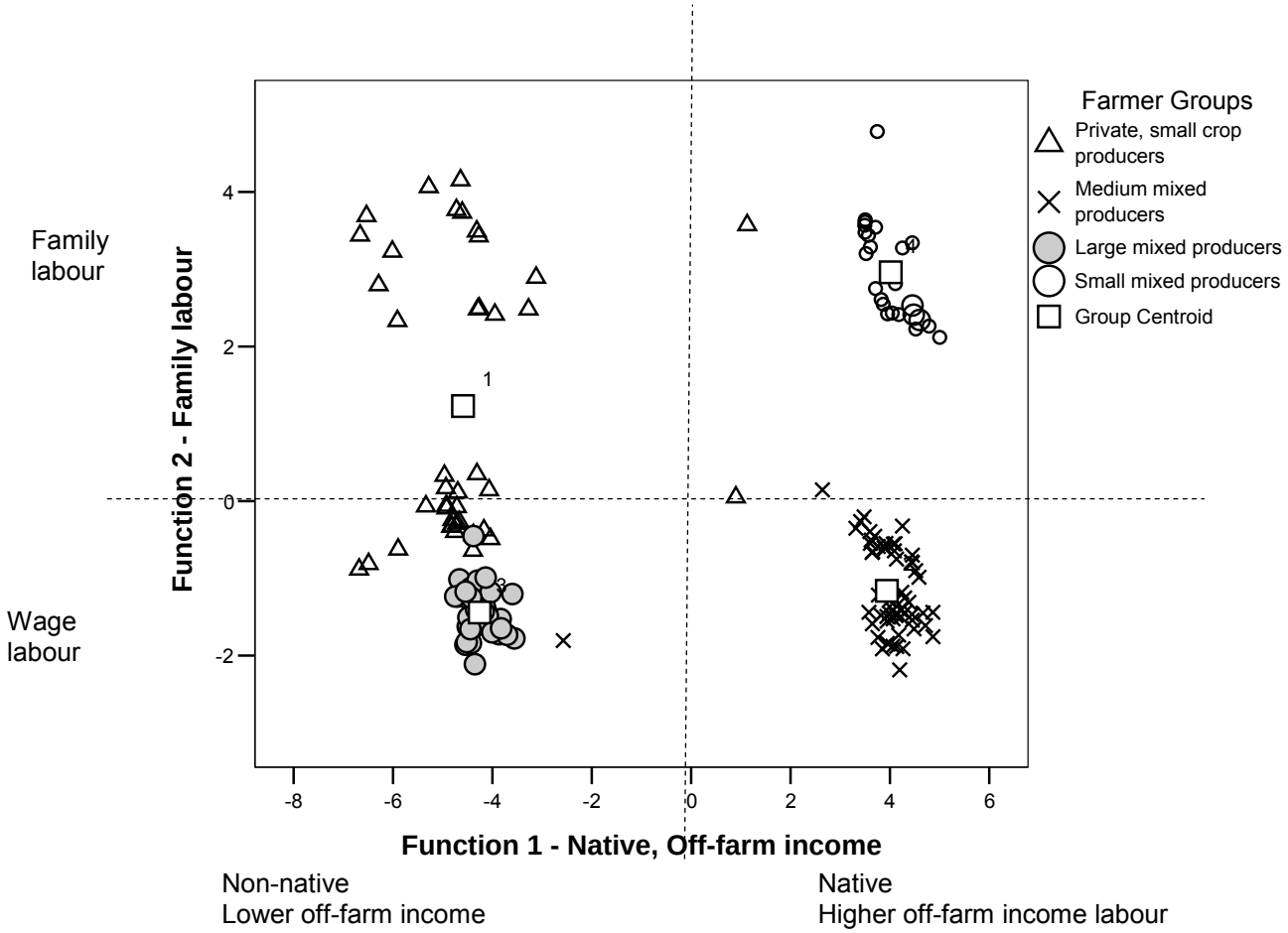

Figure 2.5. Scatter plot of the two discriminant functions. The first accounts for 18.03 Eigenvalues (84.0% of variance) and the second accounts for 2.74 Eigenvalues (12% of variance).

2.3.5. Socioeconomic characteristics of UPA farmers

2.3.5.1. Production systems

The access and use of the farming land in the Intra-urban area is either through sharing of production, rent or ownership, while in the peri-urban land could belong to the cooperatives or public sector.

In spite of selecting groups from different categories as crop producers and mixed producers, the cluster analysis did not separate the selected sample into two distinct groups. Farmer generated groups were distributed differently across different production systems. Animal raisers are dominant in the LMP group and appear together with crop producers in the MMP group while seems to be absent in the PCSP (Table 2.5).

Table 2.5. Distribution of farming systems and percentages adopting animal raising activities among farmer groups of sampled farmers (n=159) in Khartoum, 2007.

	Farmer groups			
System	Private & small crop producers (n= 40) (%)	Medium mixed producers (n= 60) (%)	Large mixed producers (n= 35) (%)	Small mixed producers (n= 24) (%)
Cooperatives	5	59	43	42
Public schemes	25	33	51	54
Private	70	8	6	4
Animal raising	5	50	77	25

Source: Field survey, 2007.

2.3.5.2. Socioeconomic Features

Generally, the main occupation of about 85 percent of respondents is farming. The LMP group showed variability in occupations among farmers. The SMP have the highest age average (about 53 years) in comparison with other groups and most of them are crop producers with the highest average experience of 34 years. On the other hand, farmers belonging to this group are moderately distributed among cooperatives and large irrigated schemes (Table 2.6).

Most of the farmers in the LMP group, who are fairly educated and have the largest average family size, have farming as secondary occupation (Table 2.6).

SMP showed the highest level of manure use per unit of farm while the PSCP showed the highest level of urea use per unit of farm (Table 2.6).

Figure 6 shows the distribution of cultivated areas by crop types, forage, leafy vegetables, and other vegetables (root and fruit vegetables) among the identified farmer groups. Private and small group showed the highest share of leafy vegetable while the other groups concentrated on forage cultivation.

Table 2.6. Socioeconomic characteristics among farmer groups of sampled farmers (n=159) in Khartoum, 2007.

Items	Farmer groups			
	PSCP (n= 40)	MMP (n= 60)	LMP (n= 35)	SMP (n= 24)
Age*** (years)	38	49	43	53
Experience years in Khartoum***	14	25	16	34
Family size*	6	8	10	7
Educated %	55	68	69	67
Main occupation (%)				
Farming	27	39	18	16
Employee	25	0	50	25
Animal raiser	0	50	50	0
others	25	25	42	8
Secondary occupation (%)				
Farming	14	33	42	9
Employee	0	0	100	0
Animal raiser	0	0	50	50
others	25	50	21	4
Manure use (ton farm^{-1} year^{-1})	2.6 (6.6)	27 (75)	37 (55)	37 (168)

Pearson-Chi-Square***.
Source: Field survey, 2007.

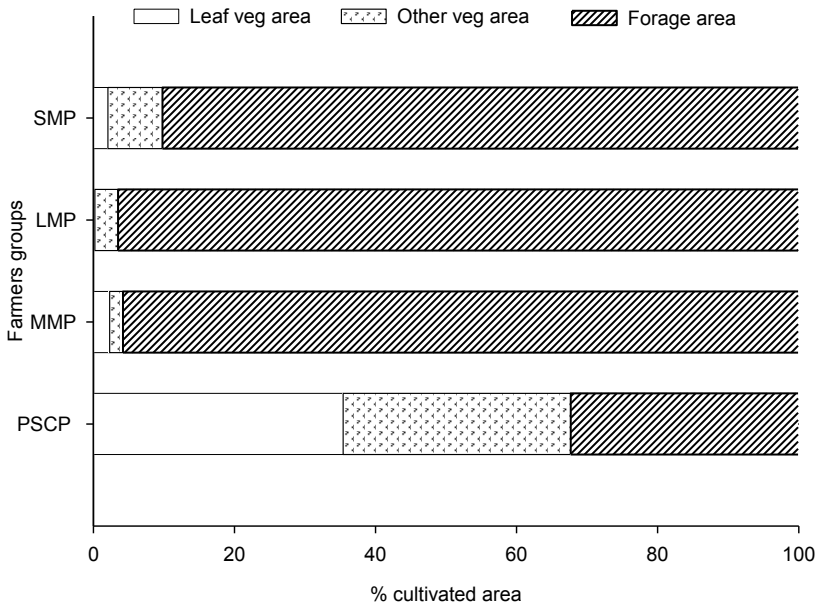

Figure 2.6. The percentages of areas per crop type for farmer groups of sampled farmers in Khartoum, 2007.

2.3.6. Priorities, advantages and disadvantages of UPA practicing

The priority behind practicing agricultural activities for both intra- and peri-urban farmers is given for food provision for household (in the form of monetary value for food to be bought from the market) followed by generation or accumulation of wealth, and then the sustaining and maintaining resources that is owned by farmers. Kendall's rank gives small value to food provision (1.51) followed by wealth accumulation (2.13) and lastly resource use (2.36) (Table 2.7). The ranks with less value showed higher importance. The low *W* "0.191" indicated the fairly agreement between farmer ranking of the three incentives (Table 7). When intra-urban and peri-urban groups are separated in the analysis, intra-urban farmers with (*W* = 0.460***) show more level of agreement compared to peri-urban respondents (*W*= 0.155***) around the incentives behind practicing agricultural activities with the same ranking for reasons within each group.

Table 2.7. Reasons for practicing agricultural activities among sampled farmers (n=108) in Khartoum, 2007.

Reason for practicing agricultural activities	Rank (mean rank)[a]
Food provision	1 (1.51)
Wealth	2 (2.13)
Resource use	3 (2.36)
Kendall's coefficient (*W*)[b]	0.191***

[a] The lower the rank, the greater the importance of the trait.
[b] W ranges from 0 (no agreement) to 1 (complete agreement) and the higher it's value the higher is level of agreement between groups.
*** $p \leq 0.001$.

UPA is one of the main providers of food and feed for human and animals within the city boundaries (Table 2.8). It also provides employment for considerable number of populations, farmers and wage labor. In the intra-urban areas, farms are located near the residential area, so farmers do not resort to fruity vegetable cultivation because of difficulty in avoiding its free access by the resident population. Most of the farmers concluded that the UPA is positive in Khartoum on account of proximity of market, higher consumption in the state and availability of inputs, beside the continuous work and daily income generation.

Table 2.8. Rank and percentage of advantages of UPA by sampled farmers (n=159) in Khartoum, 2007.

UPA positives	Frequency	
	n	%
Higher consumption of vegetable and forage	40	25.0
Availability of improved inputs in low cost and transportation services	30	18.7
Farm near animal corrals and market (easy for management)	96	60.0
Extended cultivatable areas, short plant life, daily income, continuous work the whole year	10	6.3
Availability of services: education, health, security and variability of income sources	4	2.5
Higher return and exportation facilities are available	8	5.0
Variability and availability of vegetables & and forage (self satisfaction)	8	5.0

Source: Field survey, 2007.

On the other hand farmers indicated that the constraints of UPA are: unavailability of government credit, absence of extension services, road taxes 'locally called gibana', health problems, lack of government support neither for the services provision nor for inputs, and low prices of outputs (Table 2.9).

The traditionally oriented marketing of vegetables and forage and the fluctuating prices due to seasonality are among the main obstacles for the improvement of crop production.

Table 2.9. Rank and percentage disadvantages of UPA by sampled farmers (n=159) in Khartoum, 2007.

UPA constraints	Frequency	
	n	%
Unavailability of government credit	26	16.3
Absence of extension	26	16.3
Lack of government support (Institutional) and problem of taxes/levy (gibana) on the street	47	29.4
Health problems, mosquito and Schistosomiasis, because populated area are near to farms, animal corrals, and red brick kilns	17	10.6
Product imports from other states or countries, vegetables are perishable, low prices of output, no exportation for abundant products	43	26.9
Lack of tractors for LP, low quality of inputs, no storage containers for products	5	3.1
Forage dominate, higher cost of water & electricity higher cost, and hence higher cost of production	18	11.3
Small farm size and high price for acquiring land and low soil fertility, delay in planting and low product quality, pest (weed) infestation	17	10.6
Weak institutional relations between farmers and animal producers, farmer union, and management staff	10	6.3

Source: Field survey, 2007.

2.4. Discussion

Based on socioeconomic criteria, cluster analysis revealed that urban and peri-urban farmers in Khartoum can reasonably be classified into different groups. These groups were proven to be significantly different from each other in their scale of production, i.e. farm size, cultivated crops, and number of animals. The management practices also varied significantly among the generated groups. The PSCP group, where most members are located in the intra-areas, are dominated by non-native farmers from rural agrarian areas. The farmers in this group prefer to cultivate leafy vegetables due to their daily income, continuity of farming work during the year and the intensive cultivation. They avoid cultivating fruity vegetable because of being picked by people without payment (BRYLD, 2003). The intensive cultivation is encouraged by the fertile-soil renewing characteristics during flood season besides using foliar fertilizer and urea to maintain nutrients for plants.

Animal draught is only found in the intra-urban areas due to the relatively easy land preparation for small areas and plots accompanied with the low level of off-farm income where most of them (90%) are mainly farmers. To feed the draught animal, a small area of land is used for forage cultivation.

Animal raising is obviously managed by the LMP and MMP scale farmers, coming from communities that are mainly raising animals. It exists where land is relatively larger and forage crops production is dominating to feed animals. Yet, only 11% are mainly animal raiser. MMP have relatively higher off-farm income in comparison with the LMP. The animal raiser practices the cultivation of forage activities aiming to decrease the cost of animal feed while the MMP and SMP may target the market.

Most of the farmers resort to “Bei Wagif” where crops sale is done only in the farm to avoid the complications and costs related to harvesting, transportation, road taxes and market fees.

Family labor appears among the PSCP and SMP where small farm size is managed either by farmer himself or with support from the other family members. Female labor work is mainly in the peri-urban areas where most of them belong to migrating groups from rural agrarian communities and working mainly in vegetable farms and chicken manure broadcast in the forage farms.

The LMP recorded the highest level of assets accumulation, which is still low (11%), indicating the spread of poverty among UPA farmers and revealed by farmers targeting or working for food provision for their households. Part of the intra-urban areas farmers are living in the non-permanent home located in the farm (locally referred to as “Kurnuk”) because they are coming from outside the city.

Generally cropping pattern in UPA showed wide variability in products (THOMPSON ET AL., 2010) which means decreasing risk and improving the outcome of agricultural activity in addition to raising the nutritional status of urban population (MOUGEOT, 2000). In spite of occupying a small area, leafy vegetables were of high importance and additional values for farmers. At the

same level the African leafy vegetables (ALVs) are determined as one of the important genetic resources, which are extremely important for food security, nutrition and poverty alleviation (GOCKOWSKI ET AL., 2003).

Forage is dominant in the peri-urban area around the city, under cooperatives and public schemes where organic chicken manure and chemical fertilizers, urea in most cases, are used to improve land characteristics.

Farmers depend on their own experience when dealing with farming activities, operation and input application, while also depending on the information from merchants, especially the information related to types and doses of fertilizers and pesticides, and also on their neighbouring farmers.

The native farmers in the SMP have the highest experience in agriculture in Khartoum state and most of them are educated compared to non-native farmers. Most of them are members in cooperatives and mainly working as farmers solely (92%).

Farmers revealed the factors that promote and support the UPA in Khartoum as the higher consumption of vegetables and forage, proximity to the market, availability of social services, and encouraging inputs market for the UPA. Drawbacks are lack of government support to the agricultural sector in terms of services, extension, credit, tractors, in addition to road taxes and other taxes 'gibana', small farm size, higher land prices and the instability of output prices. Marketing of vegetable crops is one of the important areas to work on to improve the UPA crop production in the city.

Considering that different groups that were covered and interviewed, crop producers, private, cooperative members, public schemes farmers, the cluster did not separate between them distinctively and this situation is described by SIEGMUND-SCHULTZE & RISCHKOWSKY (2001) as "transition groups" due to their characteristics which means the ability of farmers to shift from one system to another.

Ranking of priorities of respondents showed that they are more inclined to food provision and income seeking. The low *W* showed that practitioners have different perspectives and priorities (DOSSA ET AL., 2007) in practicing agricultural activities in the urban and peri-urban agriculture in Khartoum. This entails different plans for investigating the aspects and constraints faced by each group and responding to their needs and priorities.

Support for UPA, institutionally and financially, will be of benefit on different levels: land utilization, employment for sizable population, provision of food at lower prices in fresh and good quality, and income sources for different people.

2.5. Conclusions

The UPA in Khartoum has a relatively different criterion from other defined UPA Systems around the world. The resources used as fresh water, fertile and relatively large areas, and commercial production while the cultivation of fresh vegetables and milk seems to be available

for other urban areas. The expansions of residential areas and population have both encouraging and discouraging impacts. On the side they increase demand and on the other side decrease land areas for cultivation and increase competition for the available land, in addition to expansion on relatively unsuitable areas or resort to other income generating jobs.

The land constraint leads to intensification of land use to maximize the immediate returns but decreasing the land fertility in the long run. Some of the land owners, mainly in the intra-urban areas shift from plant production to red bricks activities to avoid the obstacles of agricultural activities.

2.6. References

ASOMANI-BOATENG, R. (2002): Urban cultivation in Accra: an examination of the nature, practices, problems, potentials and urban planning implications. Habitat International 26: 591–607.

BRYLD, E. (2003): Potentials, problems, and policy implications for urban agriculture in developing countries. Agricultural and Human Values 20: 79-86.

CBS (CENTRAL BUREAU OF STATISTICS) (2009): Sudan in figures 2004-2008. Ministry of the Cabinet, Government of the Republic of the Sudan, Khartoum.

DONGMO, T., GOCKOWSKI, J., HERNANDEZ, S., AWONO, L. D. K. and MOUDON, M. À. (2005): Peri-urban agriculture in Yaounde: its relation to poverty alleviation, economic development, biodiversity conservation and the environment. Tropicultura 23(3): 130-135.

DOSSA, L. H., WOLLY, C. and GOULY, M. (2007): Smallholders' perceptions of goat farming in southern Benin and opportunities for improvement. Tropical Animal Health and Production 39: 49-57.

ELLIS, F. and SUMBERG, J. (1998): Food production, urban areas and policy responses. World Development 26(2): 213-225.

FEULEFACK, J. F., ZELLER, M. and SCHWARZE, S. (2006): Accuracy analysis of participatory wealth ranking (PWR) in socioeconomic poverty comparisons. Discussion paper No. 44. Department of Agricultural Economics and Rural Development, Socioeconomics of Rural Development, University of Goettingen, ISSN 1433-2868.

FILMER, D. and PRITCHETT, L. (1998): Estimating wealth effects without expenditure data—or tears: with an application to educational enrollments in states of India. Policy research working paper No. 1994, The World Bank.

GOCKOWSKI, J., MBAZO'O, J., MBAH, G. and MOULENDE, T. F. (2003): African traditional leafy vegetables and the urban and peri-urban poor. Food Policy 28: 221–235.

GRAEFE, S. (2004): A survey on urban and peri-urban agriculture in Niamey, Niger. Uni-Kassel University, supported by the Vater und Sohn Eiselen-Stiftung Ulm (Germany)

GRAEFE, S., SCHLECHT, E. and BUERKERT, A. (2008): Opportunities and challenges of urban and peri-urban agriculture in Niamey, Niger. Outlook on Agriculture 37(1): 47-56.

HUNGWE, C. (2006): Urban agriculture as a survival strategy: an analysis of the activities of Bulawayo and Gweru urban farmers (Zimbabwe). Published by city farmer, Canada's Office of Urban Agriculture. Available at:
http://www. cityfarmer.org/ZimbabweSecurity.html. Accessed 11 Oct. 2010.

KHARTOUM STATE MINISTRY OF AGRICULTURE & FORESTRY (2006): Agricultural survey. Unpublished annual report.

LEECH, N. L., BARRETT, K. C. and MORGAN, G. A. (2005): SPSS for intermediate statistics: use and interpretation. Lawrence Erlbaum Associates, Publishers, Mahwah, Newjersy, London. Second edition.

MAXWELL, D. G. (1995): Alternative food security strategy: A household analysis of urban agriculture in Kampala. World Development 23(10): 1669-1681.

MCGARIGAL, K., CUSHMAN, S. and STAFFORD, S. (2000): Multivariate statistics for wildlife and ecology research. @ 2000 Springer Science+Business Media, Inc.

MOUGEOT, L. J. A. (2000): Urban Agriculture: definition, presence, potentials and risks, and policy challenges. In: BAKKER, N., DUBBELING, M., GUENDEL, S., SABEL KOSCHELLA, U. and DE ZEEUW, H. (Eds.): Growing cities, growing food, urban agriculture on the policy agenda. DSE, Feldafing, pp 1-42.

NITURAL, P. S. (2006): Urban agriculture program in the Philippines: its beginning and status. a paper presented in the workshop titled urban/peri-urban agriculture in the Asian and Pacific region, and held in Tagaytay City, Philippines, 22-26 May 2006. Available at: http://www.agnet.org/activities/sw/2006/729863362/. Accessed 11Oct. 2010.

NYAGA, E. K. (2009): A socioeconomic analysis of resources and living standards of tea and coffee smallhoders in Murang' a district, Kenya. In: DOPPLER, W., MAJDALAWI, M. and ALMOHAMED, S. (Eds.): Economics resources use and farming systems development in the Middle East and East Africa., Margraf Publishers Gmbh, 2009.

PRAIN, G. (2006): Urban harvest: a CGIAR global program on urban and peri-urban agriculture. A paper presented in the workshop titled Urban/peri-urban Agriculture in the Asian and Pacific region, and held in Tagaytay City, Philippines, 22-26 May 2006. Available at: http://www.agnet.org/activities/sw/2006/729863362/. Accessed 11 Oct. 2010.

ROVAN, J. and SAMBT, J. (2003): Socioeconomic differences among Slovenian Muncipalities: a cluster analysis approach. In: FERLIGOJ, A. and MRVAR, A. (Eds.): Development in Applied Statistics, Metodološki zvezki, 19, Ljubljana: FDV: 265:278.

SAHN, D. E. and STIFEL, D. C. (2003): Urban-Rural inequality in living standards in Africa. Journal of African Economies 12(4): 564-597.

SCHUMACHER, J., LUEDELING, E., GEBAUER, J., SAIED, A., EL-SIDDIG, K. and BUERKERT, A. (2009): Spatial expansion and water requirements of urban agriculture in Khartoum, Sudan. Journal of Arid environments 73: 399-406.

SIEGMUND-SCHULTZE, M. and RISCHKOWSKY, B. (2001): Relating household characteristics to urban sheep keeping in West Africa. Agricultural Systems 67: 139-152.

SMIT, J., RATTA, A. and BEMSTEIN, J. (1996): Urban Agriculture: An opportunity for environmentally sustainable development in Sub-Saharan Africa. Towards Environmentally Sustainable Development in Sub-saharan Africa, Environmentally Sustainable Division, Africa Technical Department (AFTES), The World Bank.

SPSS Inc. (2004): The statistical package of social science, version 13.

STOCKBURGER, D. W. (1998): Multivariate statistics: concepts, models, and applications. Missouri State University @Copyright 1996 by David W. Stockburger. Available at: http://www.psychstat.missouristate.edu/multibook/mlt00.htm. Accessed July 2008.

THOMPSON, J. L., GEBAUER, J., HAMMER, K. and BUERKERT, A. (2010): The structure of urban and peri-urban gardens in Khartoum, Sudan. Genetic Resources Crop Evolution 57: 487–500.

Appendix 2.1: Cultivated plant species at the urban and the peri-urban locations Khartoum (Sudan), 2007.

Common English name	Scientific name
Cabbage	*Brassica oleracea* L. var. *capitata* L.
Cauliflower	*Brassica oleracea* L. var. *botrytis* L.
Chard	*Beta vulgaris* L. ssp. *vulgaris* var. *cicla* L.
Cowpea, Black-eyed bean	*Vigna unguiculata* (L.) Walp. ssp. *unguiculata*
Cucumber	*Cucumis sativus* L.
Eggplant	*Solanum melongena* L.
Jew's mallow, Jute	*Corchorous olitorius* L.
Okra	*Abelmoschus esculentus* (L.) Moench
Onion: green bunching	*Allium cepa* L. var. *aggregatum* G. Don
Onion: red	*Allium cepa* L.
Pumpkin	*Cucurbita moschata* (Lam.) Duch. ex Poir.
Purslane	*Portulaca oleracea* L. ssp. *sativa* (Haw.) Schübl. Et Mart.
Rocket, Arrugula	*Eruca sativa* Mill.
Snake cucumber	*Cucumis melo* L. subsp. *melo* var. *flexuosus* (L.) Naud.
Tomato	*Lycopersicon esculentum* Mill.
White radish, Daikon	*Raphanus sativus* L. var. *longipinnatus* L. H. Bailey
Alfalfa, Lucerne	*Medicago sativa* L.
Sorghum, Milo	*Sorghum bicolor* (L.) Moench
Maize, Corn	*Zea mays* L.

Adapted from THOMPSON *ET AL.* (2010) and SCHUMACHER ET AL. (2009).

Chapter 3. Socioeconomic factors affecting farm cash income among urban farmers in Khartoum, Sudan

Abstract

The expansion of the residential areas over the last 50 years in Khartoum puts high pressure on arable land for food and feed production in and around the city. In 1993 11% of Khartoum's population owned agricultural plots planted to crops used for self-sufficiency or sale. Since then, a substantial increase in land use competition has occurred which has affected both, the urban crop production and the livestock sector.

The objectives of this study were to investigate the changes in farm resource use, and cropping patterns, and to model socioeconomic factors affecting the cash income of farmers involved. Therefore 45 crop and 30 dairy producers were randomly selected and interviewed in 2007 and again in 2009 using a semi-structured questionnaire. The information collected included age and education of the farmers, their farm location and size, cropping patterns as well as fertilizers prices and quantities, number of livestock kept, and farmers' sources of income. Descriptive and non-parametric statistics (Mann-Whitney U test) were performed to test the differences between 2007 and 2009 for the observed parameters. Generalized Estimating Equations (GEE) was used to analyze the effects of a set of socioeconomic factors on farm cash income. Within the two-year period, only a slight change in farm size (+4%) and in total livestock units (TLU) (-6%) was observed while crop intensity decreased by 25%. While urea prices varied significantly over time (z= -8.866***), the use and price of chicken manure and liquid foliar fertilizer remained rather constant. Quartiles were used to generate low and high income groups. Farmers showed mobility from high to low income groups and vice versa. The farm location (urban *versus* peri-urban) did not significantly affect farm cash income. Better education, larger farm size, and higher milk productivity significantly enhanced farm cash income while chicken manure and the area of forage decreased it. This raises questions about the use efficiency of chicken manure and of forage cultivation in the study area. Probability of farmer to join the high income group was modeled using a set of socioeconomic variables. The result showed that farm size, and family size showed significant decrease in the probability of joining the high income group while the probability was significantly enhanced by off-farm income, location and education.

Keywords: urban farms, socioeconomic factors, cash income

3.1. Introduction

Agricultural activity is sensitive to variability in environmental, social, and economic factors which are diverse over time. This variability affects the inputs used in and outputs of the agricultural activity. Many studies investigated the effect of different factors such as farm size, animal resources, crops grown, fertilizer used, technology adopted, labor, input and output markets, age and experience on farm income or performance (BÄCKMAN & SUMELIUS, 2009; DIOGO ET AL., 2011; DRECHSEL ET AL., 2004; EDMONDS, 1999; NDAMBI & HEMME, 2009; POON & WEERSINK, 2011; SHARMA ET AL., 2007; URASSA & RAPHAEL, 2002; ZHANG-LIN & YING, 2010). Urban and peri-urban agriculture (UPA) supports urban households through improving food supply and enhancing household income (DIOGO ET AL., 2011; THOMPSON ET AL., 2010). UPA responds to variations in climatic conditions and socioeconomic aspects where farmers are adapting to different changes while taking risk. Farmers have control on only some production factors especially in the short term (BÄCKMAN & SUMELIUS, 2009). Seasonality, farmer's expectations, and financial performance of the previous year are among the elements affecting the farm income of the following year (ELRASHEED & AWAD, 2009; JOHNSON & PLOTT, 1989; SHONKWILER, 1982) while the climatic conditions and socioeconomic as well as financial aspects of the farmer affect farm physical output. Generally farm income is highly sensitive to changes in inputs used, input prices, outputs produced and output prices (DIOGO, 2009; DIOGO ET AL., 2011; DRECHSEL ET AL., 2004; URASSA & RAPHAEL, 2002). At urban farms, where sensitive and perishable agricultural products are grown, changes are expected to be highly reflected on the farm performance and income and hence, on the farmers' livelihood.

Food price increase is being witnessed around the world and is affecting the production and consumption of food (BABATUNDE & QAIM, 2010). Changes in inputs and outputs prices affect the quantity and quality of food (vegetables, meat and milk) and forage produced in UPA Khartoum (ELTAYEB, 2003). The production is mainly market oriented (CBS, 2010) and is driven by the increased urbanization.

For the sake of this study two questions were raised. Firstly: is UPA of Khartoum facing changes in farm size, fertilizers used (quantity and prices) and animals owned? Secondly: are socioeconomic factors influencing the variation in farm income in the study area? The main objective of this study is to explore changes related to the farming activities in Khartoum between 2007 and 2009. The specific objectives are i) to describe and quantify the changes in crop production system such as the cropping pattern, farm size, land ownership, fertilizers amounts and prices, animal resources, and farm income. ii) to explore the relationships between the socioeconomic factors and the farm cash income and iii) to determine the effects of the socioeconomic attributes of UPA practitioners on their probability of joining higher income group among UPA practitioners.

3.1.1. Factors affecting farm income

Cash income[1] (FCI) is subject to different factors such as economies of scale, socioeconomic factors and others (PHIMISTER ET AL., 2004; POON & WEERSINK, 2011; SHARMA ET AL., 2007). FCI is equal to the cash receipts by respondents due to farming activities minus the payments done by farmer for the farming needs (PHIMISTER ET AL., 2004). PHIMISTER ET AL. (2004) indicated that cash income provides a real picture of actual income received by the farm. Net Farm Income (NFI) is defined by OLSON (2004) as "an absolute measure of profitability. It represents the returns to unpaid labour, management, and owner equity". The mentioned elements, as own labour (family labour), value of farmers own land, and assets' service in the farm, was not considered when calculating FCI. FCI is important in the short run to show the amount of money received by farmers.

Farmer's level of education and farm production system mostly remain constant overtime (SHARMA ET AL., 2007), while the inputs used, crop intensity, production cost are changeable factors (DIOGO ET AL., 2011; EL-DUKHERI ET AL., 2011; FENING ET AL., 2009). As an example the consumption of fertilizer or of animal feeds depends on prices such that when price increases the amount consumed changes with different ratios depending on the demand elasticity of the input. DIOGO ET AL. (2011) identified fertilizers, pesticides, and animal feeds as the most costly farm inputs in UPA in Niamey, Niger. These authors further observed that costs of labor, of fertilizers and of seeds strongly affected economic returns.

Farm type due to the product, crop production, livestock raising, mixed production, is a source of income variability (POON & WEERSINK, 2011). Specialization increases income volatility for crop farms while livestock farms income is much stable (POON & WEERSINK, 2011). High variability of farm income increases the likelihood for off-farm employment (POON & WEERSINK, 2011) in comparison to low variability of income. Off-farm income is one of the factors affecting farm income (POON & WEERSINK, 2011). The contribution and impact of off-farm income in the household economy vary from one community to another (BABATUNDE & QAIM, 2010). Also location and farm size affect farm income (POON & WEERSINK, 2011).

JARVIS & JERKINS (1998), using the first four years (1991-1994) of the British Household Panel survey, evidenced the variation or mobility of household income from one year to the next where the changes in income are not very large. PHIMISTER ET AL. (2004) tested the effect of a number of farm characteristics on the likelihood of a farm to move from a farm income group to another one. They investigated characteristics like farm size, type, tenure, region and farmer's age. The findings indicated that farm size positively affects cash income and that older farmers are likely to stay in low income group. Age effect on income is also mentioned by JARVIS & JERKINS (1998) where elderly people have unstable income. PHIMISTER ET AL. (2004) concludes

[1] Net cash income was defined by WOMACH (2005) as "Net cash income is gross cash income less all cash expenses such as for feed, seed, fertilizer, property taxes, interest on debt, wages to hired labor, contract labor and rent to nonoperator landlords" page 97.

that the relationship between exit and re-entry rates from and to low income group were not clear and systematic as expected (PHIMISTER ET AL., 2004).

3.1.2 Conceptual framework and model

The outcome of agricultural activity is unstable and affected by different elements (PHIMISTER ET AL., 2004). Socioeconomic factors, input-output markets, available resources, and climatic conditions are main determinant factors in agricultural activity. These factors affect farmers' decision/choice with regard to cropping pattern and inputs used. At the end it affects farm outcome (Figure 3.1).

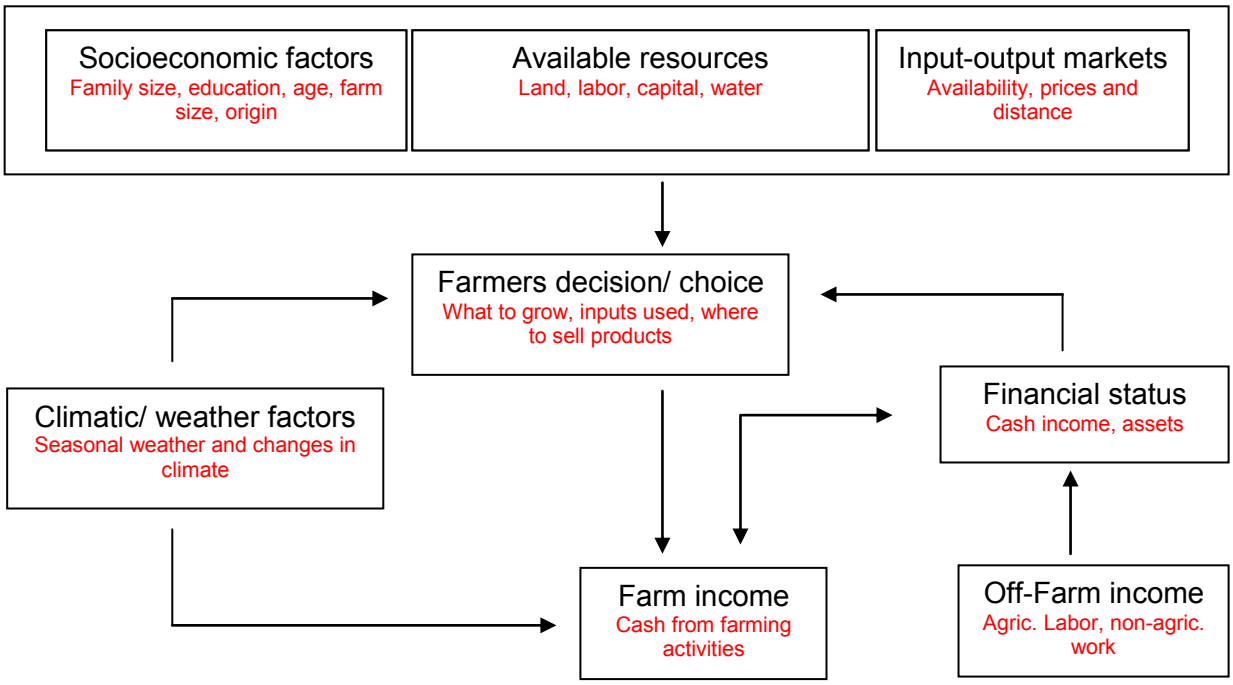

Figure 3.1. Conceptual framework: Factors affecting farmers' decision/choice and farm income. Own illustration.

Annual farm income (cash income) varies over time (PHIMISTER ET AL., 2004) partly due to farmers' choice/decision. This change may reflect the variation in productivity and price of outputs (EDMONDS, 1999; PAUDEL & WANG, 2002; PHIMISTER ET AL., 2004). Productivity and physical output are changed partially due to different factors as types and quantities of inputs used, changes in the climate/weather, and individual characteristics (PARMINTER, 1997). The farmers try to respond positively to weather and economic changes by maximizing the farm outcome.

The available production resources such as farm size and animals owned are of importance to the production scales (NDAMBI & HEMME, 2009; PHIMISTER ET AL., 2004). On the other hand the type and amounts of inputs used, such as chemical and organic fertilizer varied according to price instability, availability in the market, and transportation cost (BÄCKMAN & SUMELIUS, 2009; DIOGO ET AL., 2011; DRECHSEL ET AL., 2004). Also the variability of income sources for household affect the farm income (PARMINTER, 1997). Farm household try to

increase the farm and off-farm income through engagement of some members into off-farm income activities to improve their livelihoods.

3.2. Research methods and analysis

3.2.1. Study site

The study sites were located at Khartoum (15° 40' N, 32° 30' E, 382 m a.s.l.) and were previously described by (THOMPSON ET AL., 2010). The sites were distributed in urban and peri-urban areas mostly in Khartoum North. Daily minimum and maximum temperatures vary during winter, summer and rainfall seasons. The raining season occurs from July to September with an average annual rainfall of 155 mm.

Table 3.1 show the average annual, minimum and maximum temperature and rainfall in the study area. The rainfall shows high variability from one year to the next while minimum and maximum temperatures are relatively stable.

Table 3.1. Annual temperature in degree centigrade (min and max) and rainfall (mm year^{-1}) in Khartoum from 2003 to 2009, Sudan.

Year	Temp° C (min)	Temp° C (max)	Rainfall (mm year^{-1})
2003	23.6	37.2	153.8
2004	21.1	38.0	103.9
2005	23.8	37.9	140.7
2006	NA	NA	NA
2007	23.3	37.5	180.9
2008	24.5	38.5	80.8
2009	24.2	35.1	141.0

NA = not available.
Source: CBS statistical annual books.

3.2.2. Sampling and data collection

A total of 159 farmers (93 crop producers and 66 dairy farmers) were interviewed in 2007, being selected randomly from three subsystems: private, cooperative, and public schemes. Out of them, 75 farmers (45 crop producers and 30 dairy farmers) were interviewed again in 2009. Only those interviewed twice were used in the analysis for this part. The two surveys were conducted during July- September 2007 and July- August 2009. Information on farm size, cultivated area, cropping pattern, inputs used, animal resources, farming cost as well as farm return/income were collected using a semi structured questionnaire.

3.2.3. Data analysis

All the statistical analyses were performed using the PASW Statistics 18, Release 18.0.3 (SPSS Inc., 2009). Animal resources and animal product were calculated using Tropical

livestock units (TLU)[2] (ILCA, 1990). Descriptive statistics and non parametric technique of Mann-Whitney U test were performed to test the differences between 2007 and 2009 for the different parameters.

The return from farming activity - farm cash income (FCI) - was calculated by deducting the cash payments from the cash received by respondent.

$FCI_{it} = TCR_{it} - TCP_{it}$

Where

TCR is Total cash received by respondent from farming activities (products and by products)

TCP is Total cash paid by the respondents for the farming activities

Subscript i = the i^{th} respondents in the sample and

t = dummy for the time period: 0= 2007 and 1=2009

Negative values were observed especially among livestock keepers. Some have negative return for one year and others have negative values for both years. The quartile analysis was used to generate four income groups (FCI) for each of 2007 and 2009 where the 1st quartile (25%) determined as the low income group and coded 0 and the other three quartiles coded 1. The movements of respondents between low and high income levels during the two years were described in spite of not telling much because of the short study duration. Furthermore the immobility of income was estimated by the ratio of respondents staying at their quartile.

To model farm cash income, both quantitative (FCI) and qualitative (logit) models were used. Generalized Estimating Equations (GEE) was used to find the effect of a set of socioeconomic factors on the FCI in the study area. GEE was employed in running the model because it meets the assumptions of our study and can be applied to incomplete data (unbalanced data) (GHISLETTA & SPINI, 2004). Two references were used for data analysis: individuals (cross-sectional reference, i) and time factor (called temporal reference, t). Two assumptions were employed for this study. The first assumption is the high correlation within the individuals (respondents) due to repeated measurements while the respondents are independent (GHISLETTA & SPINI, 2004). ZEGER & LIANG (1986) has pointed out the importance of considering this correlation to obtain consistent parameters. The second assumption is that the variance of the outcome variable is to be expressed as a known function of the expectation (GHISLETTA & SPINI, 2004).

The dependant variable FCI indicates linearity so the linear scale response and identity link function was chosen because of negative income values. Robust estimator was used to estimate the covariance matrix to produce more consistent parameters.

[2] TLU of a about 250 kg were used to estimate the total herd size, based on livestock unit conversion factors for cattle (0.7), goats and sheep (0.1), horses (0.8), and donkeys (0.5).

3.2.4. Farm cash income

The relation between farm cash income and socioeconomic factors was modeled using population-averaged (PA) model as below (ZEGER ET AL., 1988)

$$FCI_{it} = \beta_0 + \beta_1 x_{1it} + \beta_2 x_{2it} + \beta_3 x_{3it} + \beta_4 x_{4it} + \beta_5 x_{5it} + \beta_6 x_{6it} + \beta_7 x_{7it} + \varepsilon_{it}$$

Where

Subscript i = the i^{th} respondent in the sample and

t = dummy for the time period 0= 2007 and 1=2009

β_0 = constant in the model

x_{1it} = farm size in hectare

x_{2it} = forage area share (% of total cultivated area)

x_{3it} = chicken manure ton ha^{-1} $year^{-1}$

x_{4it} = milk productivity liter TLU^{-1} $year^{-1}$

x_{5it} = location where 0= Peri-urban and 1= Intra-urban

x_{6it} = education where 0= not-educated, 1= educated (Intermediate school and higher)

x_{7it} = number of animals TLU (only milk animals, cows, sheep, and goats are included)

B_1, B_2, …, B_7= the coefficients associated with each explanatory variable x_{1it}, x_{2it}, …, x_{7it}

ε_{it} = random error and Var (ε_{it}) = σ_ε^2

In Gaussian distribution variance V (μ) =1. The V being a diagonal matrix with diagonal elements V (Y_{it}), V becomes $V_i = (A_i^{\frac{1}{2}} R_i A_i^{\frac{1}{2}})\emptyset$, where the A is the diagonal matrix with elements V (Y_{it}) and R is the correlation matrix, and $\emptyset$ is the dispersion parameter (BREWER, 2008). The correlation structure is assumed to be the first order autoregressive model, AR(1), which has correlation of the form, $Corr(Y_{ij}, Y_{ik}) = \rho^{|j-k|}$, i.e., homogenous variances and correlations that decline over time (BREWER, 2008; HARDIN & HILBE, 2003). Autoregressive models are appropriate for equally-spaced measurement (HARDIN & HILBE, 2003). Quasi-likelihood was used to show the model fit where the model with lower QIC was chosen as the best fit (ZEGER & LIANG, 1986). Also R^2 was calculated using the following formula (BALLINGER, 2004; HARDIN & HILBE, 2003).

R^2 marg = $1 - \frac{\sum_{t=1}^{T}\sum_{i=1}^{n}(Y_{it} - \hat{Y}_{it})^2}{\sum_{t=1}^{T}\sum_{i=1}^{n}(Y_{it} - \bar{Y}_{it})^2}$

In this equation $\bar{Y}$ is the marginal mean across all time periods $\frac{1}{nT}\sum_{i=1}^{T}\sum_{i=1}^{n} Y_{it}$

$\hat{Y}_{it}$ is predicted values after model estimation

3.2.5. Prediction of high income response

GEE with Binomial variance distribution and logit link function was used to model the effect of socioeconomic factors on the probability of the respondents to join the high income group. The dependent variable is the natural log of the probability of being in the high income group (p_{it}), divided by the probability of being in the low income group $(1 - p_{it})$. The coefficients in

the GEE binomial logit are estimated using the quasi-likelihood estimation method. The covariance matrix robust estimator and working correlation matrix AR(1) where the response is correlated due to time and correlation decreased over time, are used to get more efficient parameters.

The dependent variable is the natural log of the probability of being in the higher income group (p_{it}), divided by the probability of being in the lower income group $(1 - p_{it})$.

Formation of the model was influenced by a number of working hypotheses. It was hypothesized that a respondent's probability to gain higher income is influenced by the combined effect of a set of factors related to the respondent's socioeconomic characteristics. From these factors, seven were selected; the farm size (ha), farmer's age (years), off-farm income (%), family size (number of persons within the household), location (intra-urban or peri-urban), livestock ownership or otherwise, and education or illiteracy.

$$\mathrm{Ln}\,[Pit\,/\,(1-Pit)] = \beta_0 + \beta_1 x_{1it} + \beta_2 x_{2it} + \beta_3 x_{3it} + \beta_4 x_{4it} + \beta_5 x_{5it} + \beta_6 x_{6it} + \beta_7 x_{7it} + \varepsilon_{it}$$

Where

Subscript i = the i[th] respondent in the sample and

t = dummy for the time period 0= 2007 and 1=2009

P = probability of joining the higher income group

β_0 = constant in the model

x_{1it} = farm size in hectares

x_{2it} = farmer age (years)

x_{3it} = off-farm income (%)

x_{4it} = family size (person)

x_{5it} = location where 0= Peri-urban and 1= Intra-urban

x_{6it} =.education where 0= not-educated, 1= educated (Intermediate school and higher)

x_{7it} = keeping livestock 0= No and 1= yes

B_1, B_2, …, B_7= the coefficients associated with each explanatory variable x_{1it}, x_{2it}, …, x_{7it}

ε_{it} = random error and Var (ε_{it}) = σ_ε^2

Variance function for binomial (k) distribution V (μ) = $\mu\left(1 - {}^{\mu}/_{k}\right)$. The correlation matrix is assumed to be the first order autoregressive model, AR(1), which has correlation of the form, $Corr\left(Y_{ij}, Y_{ik}\right) = \rho^{|j-k|}$, i.e., homogenous variances and correlations that decline over time. Autoregressive models are appropriate for equally-spaced measurement (BREWER, 2008; HARDIN & HILBE, 2003). The model coefficients do not directly indicate the effect of change in the corresponding explanatory variables on the probability (*p*) of the outcome occurring. The produced coefficients using logit link function $\ln\left(\mu/(1-\mu)\right)$ reflect the effect of individual explanatory variables on its log of odds $(\mathrm{Ln}[Pit\,/\,(1-Pit)])$ (The *odds* of an occurring event

are defined as the ratio of the probability that it will occur to the probability that it will not (GUJARATI, 2003). For result interpretation the exponential value was used.

To calculate R^2 the exponentiation value, or inverse link, for predicted response was used by the following function (GUJARATI, 2003; HARDIN & HILBE, 2003):

$$p_i = \text{logit}^{-1}(z_i) = \frac{e^{z_i}}{1 + e^{z_i}}$$

Where μ is the observed value and z is predicted or estimated value and P_i is the probability (0, 1). This function was used to calculate the response and the R^2. The model with the lowest QIC was chosen as the best fit.

3.3. Results

3.3.1. Descriptive analysis

3.3.1.1. Land ownership and crop production

The total surveyed area was about 266 ha in 2007 and 275 ha in 2009 while the cultivated area, taking crop intensification into consideration, was about 654 and 497 ha in 2007 and 2009 respectively (Table 2.2). The average farm size is about 3.5 and 3.7 ha in 2007 and 2009 respectively. The decrease in the cultivated area (Table 2.2) was due to decrease in crop intensification from 232% in 2007 to 181% in 2009. Figure (2.2) shows variation in land ownership, where the land under rent and share cropping increased at the expense of owned land. In spite of relatively high increase by 83% in land area under share system the difference was not significant.

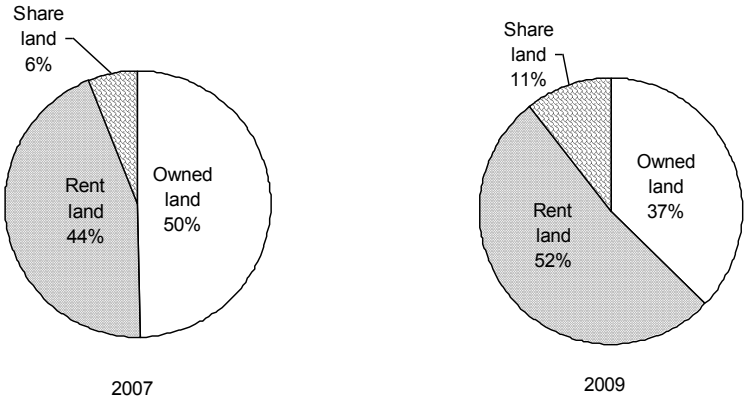

Figure 3.2. Owned land, share land, and rent land as percentage of total surveyed area among sampled farmers (n=75) in Khartoum during 2007 and 2009.

Table (3.2) shows the variation in the seasonal total cultivated area. Generally the winter is the main season but the farmers were more active in 2007 especially during summer. The cultivated land showed a high decrease of about 34% and 57% during summer and autumn and a fair increase of 15%, during winter. Only autumn cultivated area varied significantly (z = -2.036*).

Table 3.2. Total, mean (Std.), and % of farmers for surveyed, cultivated and seasonally cultivated area (ha) of sampled farmers (n=75) in Khartoum during 2007 and 2009.

Year	2007			2009			% of change in Total
Item	Total	% of farmers	Mean (Std.)	Total	% of farmers	Mean (Std.)	
Surveyed area/farm size	265.8	100	3.5 (5.8)	275.3	100	3.7 (6.8)	4
Cultivated area	616.0	100	8.2 (14.9)	497.2	100	6.6 (12.2)	-19
Seasonal cultivated area							
Summer	300.3	96	4.0 (6)	199.0	85	3.1 (4)	- 33.7
Winter	204.0	84	3.2 (5.1)	234.5	80	3.8 (9)	15.0
Autumn*	148.4	27	7.4 (16)	63.8	39	2.1 (2.6)	-57.0

Source: Field surveys, 2007 and 2009.

3.3.1.2. Cropping pattern

Table (3.3) shows the cropping pattern among surveyed farmers for both 2007 and 2009 years where the average area under cultivation decreased with different ratios. The percentage of active farmers also changed. Leafy vegetables, tomato, onion, and forage sorghum were the main grown crops (Table 3.3). During both years 2007 and 2009 forage crops dominated the study area with about 574 and 425 ha followed by leafy vegetables with 54 and 45 ha. In general leafy vegetables occupied either the same average land area or less and this is the same for almost all other crops. Faba bean, pea, and pumpkin were only grown in 2007 while other crops such as squash, gherkin, karkade and wheat were only grown in 2009. The changes in the cropping pattern do not show any significant variation for crops. But when considering crops areas cultivated during summer, winter, and autumn seasons, the cultivated area by leafy vegetables ($z = -2.042^{*}$) and forage sorghum ($z = -2.043^{**}$) during autumn showed significant difference.

Table 3.3. Mean (std.) and total area cultivated by different crops (ha) and percent farmers of sampled farmers in Khartoum State for two seasons 2007 and 2009.

year	2007			2009		
Crops	Mean ha (Std. Deviation)	% of farmers	Total	Mean ha (Std. Deviation)	% of farmers	Total
Leafy vegetable	3.84 (1.65)	18.7	53.8	3.00 (1.37)	20.0	44.97
Onion	0.64 (0.62)	12.0	5.74	0.72 (0.63)	9.3	5.04
Eggplant	0.44 (0.27)	10.7	3.49	0.35 (0.34)	5.3	1.38
Tomato	1.00 (0.84)	8.0	5.98	0.87 (0.87)	5.3	3.47
Cucumber	0.65 (0.38)	5.3	2.61	0.44 (0.4)	4.0	1.31
Sweet Potato	3.36 (0)	2.7	6.72	2.52 (1.19)	2.7	5.04
Okra	3.36	1.3	3.36	2.31 (2.08)	2.7	4.62
Sweet pepper	1.26	1.3	1.26	0.68 (0.82)	2.7	1.37
Pea	0.42	1.3	0.42			
Pumpkin	0.09	1.3	0.09			
Squash				0.23 (0.12)	2.7	0.46
Gherkin				0.32	1.3	0.32
Faba bean	0.53 (0.18)	4.0	1.58			
Wheat				2.66 (3.52)	4.0	7.98
Karkade				0.17 (0.03)	2.7	0.33
Forage sorghum	7.07 (15.69)	84.0	445.28	5.4 (11.74)	86.7	351.16
Zea Maize	4.08 (6.95)	38.7	118.36	2.95 (3.26)	28.0	61.9
Alfalfa	0.92 (0.67)	14.7	10.11	0.92 (0.57)	17.3	11.9

$p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.
Source: Field surveys, 2007 and 2009.

3.3.1.3. Prices and quantities of fertilizers

Three main fertilizer types are used in the study area, urea $(NH_2)_2CO$, foliar fertilizer (NPK), and chicken manure (raw form) (Table 4). Other fertilizers used included triple super phosphate (TSP) $Ca(H_2PO_4)_2$, and ammonium sulphate[3] (AS) $(NH_4)_2SO_4$. Fertilizer average price showed increase during 2009 but the size of increment varied among the different types (Table 3.4). Urea average price increased by 40% and chicken manure by 5% while the foliar fertilizer price decreased by 13%. The consumption of urea per farm decreased by 42% while that of chicken manure increased by 33% among sampled farmers. The variance analysis showed that only urea price varied significantly (z = -8.866***) between 2007 and 2009. Some of respondents indicated that they used TSP (13%) and AS (7%) in 2007 but not in 2009.

About 140.3 tons of urea, 137.3 liters of foliar fertilizer and 531.0 tons of chicken manure were used by all the respondents in 2007 compared to 82.2 tons of urea, 90.5 liters of foliar fertilizer and 765.0 tons of chicken manure used in 2009.

[3] 21% N and 24% sulfur (In fertilizer the purpose of the sulfate is to reduce the soil PH, used for alkaline soils).

Table 3.4. Means (Std.) and percentage change for urea, foliar fertilizer, and chicken manure prices and quantities used by sampled farmers (n=73) in Khartoum during 2007 and 2009, Sudan.

Year	2007		2009		% of Change
	Mean (Std. Deviation)	% of farmers	Mean (Std. Deviation)	% of farmers	
Price					
Urea*** (SDG ton^{-1})	916.7 (88.6)	98.7	1283.9 (190.7)	100.0	40.0
Foliar fertilizer (SDG liter^{-1})	12.1 (3.2)	25.0	10.5 (2.3)	26.7	-13.2
Chicken manure (SDG ton^{-1})	84.7 (24)	34.7	89.0 (21.4)	32.0	5.1
Quantity					
Urea (ton)	1.9 (3.3)	98.7	1.1 (1.9)	100.0	-42.2
Foliar fertilizer (liter)	7.2 (9.4)	25.3	4.5 (5.4)	26.7	-37.5
Chicken manure (ton)	23.1 (32.8)	30.7	30.6 (30.3)	33.3	32.5

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$
Source: Field surveys, 2007 and 2009.

3.3.1.4. Animal resources and animal product

Dairy cattle were the main livestock species raised by the respondents. Few goats and sheep were also kept for different purposes, such as milk, meat, selling alive or all. Average number of cows and goats owned by respondents did not show any meaningful changes between 2007 and 2009 but the total number of cows and goats kept by sampled farmers was increased by 22% and 226%, respectively. Average sheep increased notably by 482% (Table 3.5). Donkeys and horses were also kept in the animal housing, mainly to carry the green forage from the farm or market. The average TLU, which decreased by one unit did not varied significantly. The TLU kept by respondents increased by 29% because of increase of number of animal owners (Table 3.5).

The annual total milk produced was estimated at about 1,552 and 1,512 thousand liters year^{-1} in 2007 and 2009, respectively. The proportion of milk production sold was about 99.8% and 99.5% of production in 2007 and 2009, respectively. The main source of income for livestock keepers was milk sales which showed a decrease of about 25%, but not significant while milk price increased significantly (z = -6.353***) (Table 3.5). Annual milk productivity was 2,652 and 2,797 liter TLU^{-1} in 2007 and 2009 respectively.

Table 3.5. Average animals owned by sampled respondents, average milk sales (Liter year^{-1}) and milk price (SDG liter^{-1}) during 2007 and 2009 in Khartoum, Sudan.

Year	2007			2009			% of change in mean
	Mean (Std. Deviation)	% of respondents	total	Mean (Std. Deviation)	% of respondents	total	
Owned animals							
Old cow	27.0 (30.1)	40.0	811.0	27.4 (41.2)	48.0	988.0	1.5
Old goat	11.3 (10.3)	8.0	68.0	11.7 (9.4)	25.3	222.0	3.5
Old Sheep	4.5 (2.1)	2.7	9.0	26.2 (35.3)	14.7	288.0	482.2
Old donkey	2.0 (.)	1.3	2.0	1.9 (1.5)	22.7	33.0	-5.0
Old horse	1.0 (.)	1.3	1.0	1.67 (1.1)	16.0	20.0	70.0
Tropical livestock unit[a]	19.2 (21.0)	40.0	575.4	18.1 (28.6)	54.7	742.6	-6.1
Milk production							
Milk sales (Liter year^{-1})[b]	57375 .0 (52230.4)	36.0		47039.6 (50728.4)	44.0		-20
Milk productivity liter TLU^{-1} year^{-1}	2652.0 (913.8)	37.3		2797.4 (2022.5)	45.3		5
Milk prices (SDG Liter^{-1})***	1.2 (0.21)	37.3		1.8 (0.23)	42.6		50

a Only cow, sheep, and goats.
b Conversion factor 1 liter = 2.2 pound.
* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.
Source: Field surveys, 2007 and 2009.

3.3.1.5. Annual farm cash income

Both crop producers and livestock keepers faced erratic price changes in 2009 in comparison to 2007 for inputs and outputs with different ratios. The annual farm cash income showed high variation with an average of 4,189 and 4,249 SDG in 2007 and 2009, respectively (Table 3.6). Some respondents incurred negative income especially among livestock keepers in the peri-urban settings. In spite of high variation, the analysis showed that income did not vary significantly between locations, intra- and peri-urban, production systems, crop producers and mixed producers, or years, 2007 and 2009.

Farm income mainly comes from crop sales and/ or animal and animal products sales. As shown in Figure 3.3, 8% and 7% of respondents were totally depending on animal production for income in 2007 and in 2009, respectively. The average annual income from crop production was 70% and 65% in 2007 and 2009 respectively. With regard to animal production the average contribution of milk sales to income slightly decreased from 84% in 2007 to 82% in 2009. Dependency on live animal sales increased slightly by 22% (Table 3.6).

Table 3.6. The contribution of crop production to farm income, and share of animal products and sales in the income from animal production, among sample farmers (n= 73) in Khartoum, seasons 2007 and 2009, Sudan.

Years	2007	2009
Farm income[a]	4188.5 (18516.8)	4248.8 (12802.5)
Average crop return %	70.4	64.7
Livestock return		
Live animals sales %	12.2	14.9
Milk sales %	83.5	81.6
Manure sales %	4.3	3.5

[a] mean (standard deviation).
Source: Field surveys, 2007 and 2009.

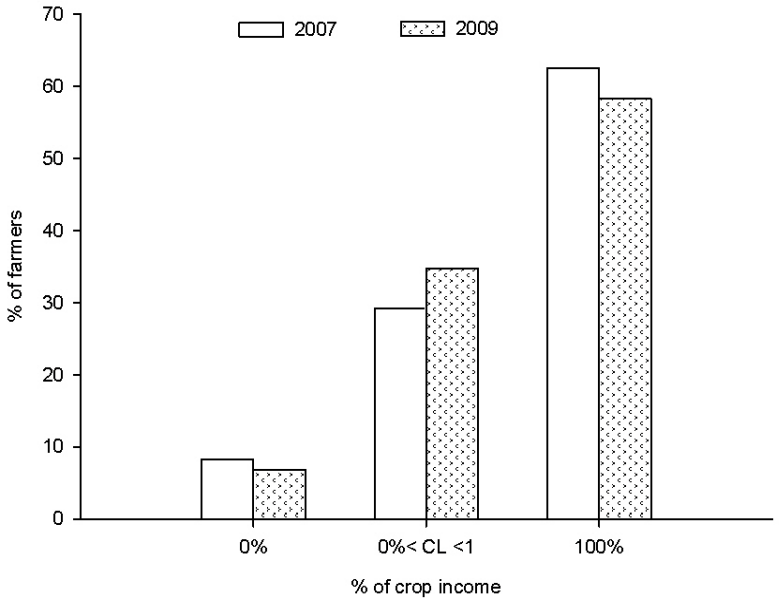

Figure 3.3. The contribution of crop sales in farm cash income among sampled farmers (n=75) in Khartoum in 2007 and 2009.

3.3.2. Factors influencing farm cash income

The relationships between a set of some socioeconomic factors and farm cash income were explored (Table 3.7). The selected factors were farm size (ha), education (1, 0), location (intra-urban *versus* peri-urban), milk productivity (liter TLU^{-1} $year^{-1}$), livestock owned TLU, chicken manure (ton ha^{-1}), and forage area (% from total).

Table 3.7. Parameters Estimates and Standard Errors for GEE with Gaussian variance distribution and identity link function for factors affecting farm income among sample farmers (n= 73) in Khartoum 2007 and 2009, Sudan.

	GEE, Normal distribution, AR(1) correlation	*P* value	SE
Intercept	6760.73	.099	4099.485
Location (1= Intra-urban, 0 otherwise)	-3462.25	.457	4658.26
Educated (1= educated, 0 otherwise)	7253.09**	.004	2527.21
Farm size (ha)	2086.95***	.001	600.76
Milk productivity (liter TLU^{-1})	2.43*	.041	1.19
Chicken manure (ton ha^{-1})	-491.94*	.038	237.37
Forage area share (%)	-139.92**	.003	47.51
Total livestock units (TLU)	-195.23	.303	189.47
Scale	1.772E8		
R2 (R^2 marg)	0.333		
Working correlation estimates (AR1)	.367		
(QIC)[a ,b]	2.322E10		
(QICC)[a ,c]	2.322E10		

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.
a. Computed using the full log quasi-likelihood function.
b. Quasi Likelihood under Independence Model Criterion.
c. Corrected Quasi Likelihood under Independence Model Criterion.

Factors as farm size, milk productivity, and education showed positive and significant effects on the FCI. The results showed that an increase in farm size of 1 ha would lead to an increase in farm income by about 2,089 SDG if other variables remained constant. Educated farmers significantly earn higher income in comparison to non-educated farmers. Raising animals had a negative but non-significant influence on FCI. Increase in milk productivity by 1 liter TLU^{-1} will increase FCI by about 2.4 SDG. Use of chicken manure had a negative impact on income where an additional ton ha^{-1} will likely lead to a decrease in FCI by 492 SDG. Similar result was obtained for forage cultivated area whereby an increase of the area grown by forage by 1% will decrease FCI by 140 SDG. The location of urban agriculture (intra- and peri-urban) shows negative sign but with no significant effect on farm income. Scale parameter (dispersion parameter), 1.772E8, is lower than the variance of income for whole sample (2.522E8).

Working correlation matrix (AR1) was used due to the hypothesis of equally spaced measurements and correlation decreased over time. The value 0.37 reflected a relatively weak correlation within respondents. Coefficient of determination R^2 showed that this model explained only 33% of variance in the response variable. The model with less QIC was chosen as the more fitted model.

3.3.3. Low income group

The average cash income varied among respondents in 2007 and 2009. Generally farmers showed better-off situation in 2009 than 2007. Four income groups were generated for each year 2007 and 2009. The fourth (25%) group was chosen to be the low income group. The level of low group income was 127.8 and 924.2 SDG year^{-1} in 2007 and 2009 respectively. Table 3.8 showed farmers movement from and to low income group during the two years with consideration to the short period. Seven farmers remained in the low income group for both years, while 11 moved from the low income group to the high income group, 41 farmers remained in the higher income group for two years and the rest moved from high to low income group. The ratio of respondents staying at their quartiles was 35%, 29%, 44% and 50% for the quartiles 25%, 50%, 75%, and 100% respectively (25% is lower income group).

Table 3.8. Number of respondent under low income and higher income groups during 2007 and 2009 for sampled respondents (n=70) Khartoum, Sudan (mobility matrix).

Year 2007	Year 2009		Total sample
	Low income	Higher income	
Low income	7	11	18
High income	11	41	52
Total	18	52	70

Source: Field surveys, 2007 and 2009.

The farmers in the low income group showed a larger average farm size of 3.1 ha, family size of 8 person and younger age of 42 years, in comparison to 2.5 ha, 6 person and 45 years of age for high income group in 2007 and the same for 2009 (Table 3.9). Six per cent of them were in urban area in 2007 and 0% in 2009 while 33% were educated in 2007 compared to 39% educated in 2009 (Table 3.9). Farm size (z= -2.671**) and family size (z= -2.719**) varied significantly between income groups in 2007 but the difference in 2009 was not significant. Eighty three per cent of the low income group in 2007 were livestock keepers compared to 56% in 2009. Off-farm income percentage varied along time. 60% of sampled farmers have 0 off-farm income in 2007 compared to 45% in 2009. Mann-Whitney U test indicates a significant difference between income quartiles at 2007 (z= -2.190*) but not 2009 (Table 3.9).

Table 3.9. Mean and standard deviation for farm size, farmers age, family size, off-farm income and % of intra-urban, educated, and livestock keepers for low (n=18) and high (n= 53) income farmers among sample farmers 2007 and 2009.

Year	2007		2009	
Income groups	Low income Mean (Std. Deviation)	High income Mean (Std. Deviation)	Low income Mean (Std. Deviation)	High income Mean (Std. Deviation)
Farm size (ha)	3.1 (1.9)	2.5 (3.4)	3.2 (3.4)	2.8 (3.7)
farmer age (years)	42.2 (13.4)	44.8 (13.1)	47.5 (15.1)	46.1 (12.3)
family size (person)	8.1 (3.8)	6.1 (3.2)	10.9 (10.4)	7.8 (4.7)
Off-farm income (%)	6.2 (14.7)	24.9 (31.4)	23.1 (28.6)	29.8 (32.7)
Location (Intra-urban) (%)	5.6	26.4	0.0	28.3
Education (educated) (%)	33.3	52.8	38.9	52.8
Livestock keeping (%)	83.3	25.0	55.5	54.0

Source: Field surveys, 2007 and 2009.

3.3.4. Factors influencing the probability of joining high income group

The movements between low and high income groups were affected by many factors. The probability of farmers to join high income group was predicted in this study using a set of socioeconomic factors (Table 3.10).

Farm size showed positive and significant effect on the probability (*p*) of higher farm income odds. An increase in farm size by 1 ha was likely to increase the probability of farmers to get higher farm income by 1.24 times. The same is applicable for off-farm income which showed positive and significant effect on the *p*. Increase in off-farm income by 1% was likely to increase the farm income by a unit of 1. Intra-urban location shows positive and significant effect with higher potentiality, 25 times to get higher income than peri-urban farmers. Education showed a significant and positive effect on farm income whereby educated farmers were likely to get 3.8 times more income than non-educated farmers. Family size showed negative and significance effect on the probability of getting higher farm income. Both farmer's age and livestock keeping showed no significant effect on probability of getting higher income. The scale parameter is 1 and coefficient of determination showed that this model explained 25% of variance in the response variable.

Table 3.10. Parameters Estimates and Standard Errors for GEE with binomial variance distribution and logit link function for factors affecting joining high farm income among sample farmers (n= 73) in Khartoum 2007 and 2009, Sudan.

	GEE , binomial distribution, AR(1) correlation	SE	*P*	Odds Exp(B)
Constant	-0.539	1.1741	0.646	.583
Farm size (ha)	0.217	0.0898	0.016	1.242*
Farmer age (years)	0.019	0.0192	0.312	1.020
Off-farm income (%)	0.019	0.0073	0.008	1.019**
Family size (persons)	-0.105	0.0449	0.019	.900*
Urban agric (1= intra-urban, 0= pu)[$]	3.224	1.2672	0.011	25.123*
Own animal (1= yes, 0= no)	-0.833	0.5233	0.112	.435
Educated (1= educated, 0 otherwise)	1.328	0.4913	0.007	3.775**
Scale	1.06			
R^2 (R^2marg)	0.25			
Working correlation matrix (AR1)	-0.168			
(QIC)[a,b]	137.418			
(QICC)[a,c]	139.437			

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$.
$ pu = peri-urban.
a. Computed using the full log quasi-likelihood function.
b. Quasi Likelihood under Independence Model Criterion.
c. Corrected Quasi Likelihood under Independence Model Criterion.

3.4. Discussion

Total cultivated land and owned livestock showed a change from 2007 to 2009. While the average farm size was almost the same, land ownership showed variation where the land owned was decreased and rent and share cropping was increased. This simultaneously happened with decrease in crop intensity. This may indicate the limited resources of suitable land while ownership status and crop intensity depends on financial status of the farmers (CASAVANT ET AL., 1999). On the other hand the seasonally cultivated area showed notable change but only autumn cropping indicated significant variation between 2007 and 2009. All this indicated flexibility in farming activities along time. Analysis of cropping pattern shows that some crops were grown always as leafy vegetables and forages. Other vegetables are grown in different average area and varied number of farmers.

Average amount of urea (ton farm^{-1}) consumed in 2009 was less than in 2007. This decrease seems to relatively reflect price increase and the decrease in the cultivated areas. The

amount of chicken manure[4] consumed (ton farm^{-1}) was increased where the ratio of price increase was less than with urea. The urea and chicken manure were the mostly used fertilizers in addition to foliar fertilizer. Urea and chicken manure seem to be used as substitutes in peri-urban areas (Olson, 2011).

Total number of livestock kept by farmers was increased and even the number of keepers among farmers was increased. The latter indicated that some farmers were willing to expand their activities. On the other hand some of them keep livestock for home consumption (subsistence). Average TLU did not show change but average annual milk sales decrease by 20%. Milk productivity and milk price showed slight increase. Increase in milk price could be due to increase in production cost mainly feed cost, either green forage or supplementing feed (DIOGO, 2009).

Average income from crop sales was 70% in 2007; decreasing to 65% in 2009. About 63% of respondents depend only on crop sales for income in 2007 compared to 58% in 2009. Income from livestock is 100% for 8% of respondents in 2007 compared to 7% in 2009 while other livestock keepers sell forages to generate some income. This contradicts POON & WEERSINK (2011) who indicated that specialization increases income volatility for crop farms and not livestock farms. Among livestock keepers income from live animal sales increased slightly from 12% in 2007 to 15% in 2009. This movement can tell us something about farmers' strategies to improve their farm income where some livestock keepers try to cover part of high expenses through crop sales and crop producers try to expand to livestock production to overcome the risk in crop production. All this shows farmers' inclination towards flexibility in activity choice in order to raise farm income (POON & WEERSINK, 2011).

The FCI showed large standard deviation which is an indicator for over dispersion due to the instability in agricultural activities (BREWER, 2008; POON & WEERSINK, 2011). The generated income quartiles showed that respondents moved from low to high farm income and vice versa within each quartile (PHIMISTER ET AL., 2004). This movement explains continuity momentum in practicing agriculture in spite of negative incomes faced in many years (ELRASHEED & AWAD, 2011). The data do not show much due to short duration of the study period (2 years). Income mobility and instability was better explained by PHIMISTER ET AL. (2004) where they used data of 6 and more years (between 1988/89 and 1999/2000) to explore the mobility of income among respondents. As PHIMISTER ET AL. (2004) indicated, the medium farm size has positive and significant effect on exit from and re-entry in low cash income group. JARVIS & JERKINS (1998) indicated that "*the longer the elapsed interval the greater the degree of mobility observed*". Further, he also indicated that most mobility is short-ranged; for example, the mobility from one year to the next year is greater than to the third or fourth year.

GEE normal distribution and identity link was used to model the marginal income for respondents and binomial distribution logit function was used to model the probability of getting

[4] The nutrient content of chicken manure was investigated by YOUSIF & MUBARAK (2009).

higher income among respondents. PA (populations averaged) model describes how the average income across respondents changes with the selected socioeconomic factors (ZEGER ET AL., 1988). The socioeconomic factors that reflected on income showed different impact. Location, intra- and peri-urban status, shows significant effect on the level of income, whether low or high. The result indicates that intra-urban farmers gain less incomes, but with more stability. On other way farmers in peri-urban settings could gain high or very low incomes. Farm size shows significant and positive effect on the amount of income, similar to the findings of PHIMISTER ET AL. (2004), but also significant and negative effect on the level of income. This could be explained when we know that the large farms were located in the peri-urban area. Some of them are mixed farms that grow forage crops to feed own animals and/or for market. Forage area share (%) shown significantly negative effect on the amount of income. But livestock number and livestock ownership did not show significant effect on the amount of income and level of income, respectively. But showing negative effect on the amount of income by number of animals was matched expectations where significant contribution of small scale dairy farming to household income has also been reported elsewhere (LWELAMIRA ET AL., 2010; URASSA & RAPHAEL, 2002). NDAMBI & HEMME (2009) stated that "*Larger farms have higher incomes and entrepreneur's profit than smaller farms of the same production system and country, except in the extensive farms of Uganda the 3-cow farm is more profitable than the 13-cow farm".* SHARMA (2007) found that the herd size have significant effect on annual gross income from crop and dairy farming systems but not on the net income.

One of the interesting correlations was that found between forage area and concentrates kg TLU^{-1} $year^{-1}$ which showed significant and positive, but not high, r value (0.236**) and the same applies for TLU (0.303**). The correlation between the TLU and concentrates kg TLU^{-1} $year^{-1}$ was not significant and rather weak (0.135).

Chicken manure showed negative and significant effect on farm cash income. Research provides evidence for the positive and significant effects of chicken manure on forage production (ABUSUWAR & EL ZILAL, 2010; ELSHEIKH ET AL., 2006). But the investigated amounts (7.5, 8, and 10 ton ha^{-1}) were less than that amounts used by sampled farmers (13.1 ton ha^{-1} in 2007 and 16.6 ton ha^{-1} in 2009). ELRASHEED & AWAD (2009) indicated that farmers producing potato in Khartoum are using resources inefficiently. Family size showed negative and significant effect on the level of farm income. Some of family members participate in the farm work in the peri-urban case while for the intra-urban, farmers do the job alone or employ wage labor. In general, other family members engage in other activities as POON & WEERSINK (2011) BABATUNDE & QAIM (2010) reported, indicating competition for family labor between farm and off-farm work. Off-farm income had positive and significant effect on the level of farm income. As BABATUNDE & QAIM (2010) observed, off-farm income significantly affects farm income where farmers could use more fertilizer, pesticides, and hired labor. On the other hand, together with farm income, off-farm income was reported to have positive impact on food security and

nutrition in the rural Nigeria (BABATUNDE & QAIM, 2010). In the covariance matrix off-farm income shows negative sign with all variables in the model except family size and farm size. This indicates that other family members could support the farm income through doing some other jobs (POON & WEERSINK, 2011).

For binomial logit model the scale parameter is 1 which means that the model is good (BREWER, 2008). On the other hand, the large scale parameter for the Gaussian model indicates over-dispersion in the farm cash income. Taking into consideration the difficulty in covering all factors affecting farm income, yet output price is an important factor. But because of variability in products its inclusion in the model became difficult.

The repeated measurements, panel data, give more reliable results than one measurement or cross-sectional data set (SADASHIVAPPA, 2009). SADASHIVAPPA (2009) mentioned that individuals are heterogeneous and panel data has greater capacity for capturing the complexity of human behaviour and improving the efficiency of econometric estimates than single cross-sectional data. For the sake of this study the sampled farmers are interviewed twice in 2007 and 2009. During the second interview in 2009 it was difficult to locate all farmers again. Some of them changed their farm locations, some were no more farming lands, and some could not be met for other reasons. In this case when the number of respondents varied from one data layer to the next, this produced unbalanced data sets (GHISLETTA & SPINI, 2004). GEE is powerful in dealing with this type of data. The benefit of GEE is the accountability for correlation where ZEGER & LIANG (1986) stated that "*Correlation is anticipated among a subject's measurements … it must be accounted for to obtain a correct statistical analysis*".

In the Gaussian model there is a need to consider the Wald test statistics with caution because of large value of regression parameters (Ballinger, 2004). The short duration of this study of two years, although giving a better picture than with one year, it still evident that the more years are covered, the more reliable the result would be.

3.5. Conclusion

Farming in urban Khartoum is high variable in dealing with resources, input use and production. The farm size, cropping pattern, fertilizers amounts and prices, animal resources and farm income depict changes, with increasing or decreasing ratios from season to season. Farmers respond to changes in prices and climate to enhance farm income. Variability in income sources and crops grown were reported. The socioeconomic factors reflect significant effect on farm cash income. Dairy production involves showed lower efficiency in input use in comparison to crop production. Dairy producers prefer to grow forage to feed their animals and undertake partial sales. In addition, the areas grown with forage are increasing at the expense of vegetable crops. This needs intervention from government to redevelop use of resources, support urban farmers and increase production efficiency. Urban agriculture is characterized by shifts of producers in joining high or low income groups, where intra-urban farmers show higher

probability to join high farm income groups. Yet, this conclusion should be taken with care due to the short, two-year study duration. More frequent observations and data collection methods would more effectively serve studying the efficiency of use of resources in urban farming. More follow up with farmers should be adopted for the improvement of farming in UPA Khartoum.

3.6. References

ABUSUWAR, A. O. and EL ZILAL, H. A. (2010): Effect of chicken manure on yield, quality and HCN concentration of two forage Sorghum (*Sorghum bicolor* (L) Moench) cultivars. Agriculture and Biology Journal of North America 1(1): 27-31.

BABATUNDE, R. O. and QAIM, M. (2010): Impact of off-farm income on food security and nutrition in Nigeria. Food Policy 35: 303-311.

BÄCKMAN, S. and SUMELIUS, J. (2009): Identifying the driving forces behind price fluctuations and potential food crisis. Discussion Papers No35, Department of Economics and Management, University of Helsinki. Available at: http://www.mm.helsinki.fi /mmtal/abs/DP35.pdf. Accessed 23 June 2010.

BALLINGER, G. A. (2004): Using generalized estimating equations for longitudinal data analysis. Organizational Research Methods 7(2): 127-150.

BREWER, C. (2008): Using generalized estimating equations with regression splines to improve analysis of Butterfly transect data. A thesis submitted for the degree of M. Phil at the University of St. Andrews.

CASAVANT, K. L., INFANGER, C. L. and BRIDGES, D. E. (1999): Agricultural economics and management. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

CBS (CENTRAL BUREAU STATISTICS) (2010): Fifth population census 2008. Available at: http://www.cbs. gov.sd/Tiedadat/Tiedadat5th.htm. Accessed 7 July 2010.

DIOGO, R. V. C. (2009): Horizontal nutrient fluxes and production efficiencies in urban and peri-urban crop and livestock husbandry of Niamey, Niger. Dissertation presented to the Faculty of Organic Agricultural Sciences/ Group Animal Husbandry in the Tropics and Subtropics University of Kassel.

DIOGO, R. V.C., BUERKERT, A. and SCHLECHT E. (2011): Economic benefit to gardeners and retailers from cultivating and marketing vegetables in Niamey, Niger. Outlook on Agriculture 40(1): 71–78.

DRECHSEL, P., GIORDANO, M. and GYIELE, L. (2004): Valuing nutrients in soil and water concepts and techniques with examples from IWMI studies in the developing world. International Water Management Institute, Research report 82.

EDMONDS, C. M. (1999): The effect of technology transfer program participation on small farms in Chile. Selected paper for presentation at the Annual Meeting of the American Agricultural Economics Association, August 8-11, 1999, in Nashville, Tennessee.

EL-DUKHERI, I., ELAMIN, N. and KHERALLAH, M. (2011): Farmers' response to soaring food prices in the Arab region. Food Security 3(1): 149-162(14).

ELRASHEED, M. M. M. and AWAD, F. H. B. (2009): Economics of potato production and marketing in Khartoum State. Journal of Science and Technology 10(2): 80-91.

ELSHEIKH, E. A.E., ELNESAIRY, N. N. B. and MAHDI, A. A. (2006): Effect of *Sinorhizobium* Inoculation and chicken manure on nodulation and forage yield of Alfalfa (*Medicago sativa*

L.) under irrigation in a semi-arid environment. University of Khartoum Journal of Agricultural Sciences 14(2): 182–197.

ELTAYEB, G. E. (2003): The case study of Khartoum, Sudan. In: Understanding slums: case studies for the global report on human settlements 2003. Available at: http://www.ucl.ac.uk/dpu-projects/Global_Report/pdfs/khartoum_bw.pdf. Accessed 30 May 2010.

FENING, J. O., YEBOAH, E., ADJEI-GYAPONG, T. and GAIZIE, E. (2009): On farm evaluation of the contribution of three green manures to maize yield in the semi-deciduous forest zone of Ghana. African Journal of Environmental Science and Technology 3(9): 234-238.

GHISLETTA, P. and SPINI, D. (2004): An introduction to generalized estimating equations and application to assess selectivity effects in a longitudinal study on very old individuals. Journal of Educational and Behavioral Statistics 29(4): 421-437.

GUJARATI, D. N. (2003): Basic econometrics. Fourth Edition, The McGraw-Hill Companies, Inc.

HARDIN, J. W. and HILBE, J. M. (2003): Generalized estimating equations. Champan & Hall/CRC.

ILCA (INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA) (1990): Livestock Systems Research Manual. Working Paper 1, vol. 1, (ILCA, Addis Ababa, Ethiopia) Available at: http://www.fao.org/wairdocs/ilri/x5469e/x5469e08.htm#inter species composition of the livestock holding. Accessed 11 Apr. 2011.

JARVIS, S. and JERKINS, S. P. (1998): How much income mobility is there in Britain?" The Economic Journal 108: 428-443.

JOHNSON, M. D. and PLOTT, C. R. (1989): The effect of two trading institutions on price expectations and the stability of supply-response lag markets. Journal of Economic Psychology 10: 189-216.

LWELAMIRA J., BINAMUNGU H. K. and NJAU F. B. (2010): Contribution of small scale dairy farming under zero-grazing in improving household welfare in Kayanga ward, Karagwe District, Tanzania. Livestock Research for Rural Development 22, Article #31 available in http://www.lrrd.org/lrrd22/2/lwel22031.htm. Accessed 24 May 2011.

NDAMBI, O. A. and HEMME, T. (2009): An economic comparison of typical dairy farming systems in South Africa, Morocco, Uganda and Cameron. Tropical Animal Health and Production 41: 979-994.

OLSON, K. D. (2004): Farm management: principles and strategies. First edition, Iwa State Press.

OLSON, K. D. (2011): Economics of farm management in a global setting. John Wiley and Sons, Inc.

PARMINTER, I. (1997): Off-farm income: Theory and Practice. Rural Policy, MAF Policy, Technical Paper 97/5, ISBN 0-478-07447-6, ISSN 1171-4662, June 1997. Available at: http://www.maf.govt.nz/mafnet/rural-nz/profitability-and-economics/ employment/off-farm-income-theory-and-practice/ofincth2.htm. Accessed 9 Dec. 2010.

PAUDEL, K. P. and WANG, Y. (2002): Part time farming, farm productivity, and farm income: evidence from the Southeast US unpublished paper presented in the American Agricultural Economics Association's annual meeting held in Long Beach, California July 28-31, 2002. Available at http://ageconsearch.umn.edu/bitstream/19594/1/sp02pa05.pdf. Accessed 4 Aug. 2010.

PHIMISTER, E., ROBERTS, D. and GILBERT, A. (2004): The dynamics of farm incomes: panel data analysis using the Farm Accounts Survey. Journal of Agricultural Economics 55(2): 197-220.

POON, K. and WEERSINK, A. (2011): Factors affecting variability in farm and off-farm income. Structure and Performance of Agriculture and Agri-products Industry Network, working paper #2011-3.

SADASHIVAPPA, P. (2009): Adoption and impacts of transgenic Bt cotton technology in India: a panel data approach. Cuvilllier Verlag, Goetingen.

SHARMA, Y. K., BANGARVA, G. S. and SHARMA, S. K. (2007): Factors affecting gross and net income of farmers in different farming systems. Indian Research Journal of Extension Education 7(1): 51-56.

SHONKWILER, J. S. (1982): An empirical comparison of agricultural supply response mechanisms. Applied Economics 14: 183-194.

SPSS, Inc. (2009): Chicago, IL, http://www.spss.com.

THOMPSON, J., GEBAUER, J., HAMMER, K. and BUERKERT, A. (2010): The structure of urban and peri-urban gardens in Khartoum, Sudan. Genetic Resources Crop Evolution 57: 487–500.

URASSA, J. K. and RAPHAEL, E. (2002): The contribution of small scale dairy farming to community welfare: a case study of Morogoro municipality. Electronic publications from Sokoine University of Agriculture, Morogoro, Tanzania, Available at: http://www.fiuc.org/esap/MOROG/MOROG5/General/dairyfarming.pdf. Accessed 15 May 2011.

WOMACH, J. (2005): Agriculture: a glossary of terms, programs, and laws, 2005 Edition. CRS Report for Congress Order Code 97-905 Available at: http://ncseonline.org/nle/crsreports/05jun/97-905.pdf. Accessed 9 Dec. 2010.

YOUSIF, A. M. and MUBARAK, A. R. (2009): Variation in nitrogen mineralization from different manures in semi-arid tropics of Sudan with reference to salt-affected soils. International Journal of Agriculture and Biology 11(5): 515-520.

ZEGER, S. L. and LIANG, K. (1986): Longitudinal data analysis for discrete and continuous outcomes. Biometrics 42: 121-130.

ZEGER, S. L., LIANG, K. and ALBERT, P. S. (1988): Models for longitudinal data: a generalized estimating equation approach. Biometrics 44: 1049-1060.

ZHANG-LIN, X. and YING, N. (2010): Factors affecting the income of farmers. Asian Agricultural Research 5(2): 18-20.

Chapter 4. Potential of urban and peri-urban agriculture: The role of vegetable markets in Khartoum, Sudan

Abstract

The importance of urban agriculture (UA) is evident worldwide. Encouraged by high consumption, urban markets in the developing countries receive high flows of vegetables and fruits originating from urban production and attract vegetable and fruit production from other regions around the city because of relatively higher prices. Khartoum market is the biggest market in Sudan for vegetables and fruits. As price takers, producers always have concern about the market. The market is usually either supportive or a risk source for producers with regard to food production, especially perishable vegetables. The main objectives are to identify the source of vegetables to urban market and to identify the relationship between dealers and producers, beside the trend of vegetables wholesale and consumer prices during one year. Hence weekly whole sale prices were collected from Shambat central market all year: from February 2009 to January 2010. Informal interviews were conducted with the traders in the market. Descriptive, non-parametric Kruskal-Whallis test, parametric one-way ANOVA test, and graphs were used to analyse the collected information. Consumer real price was calculated before the analysis. Results indicated that vegetables flow from different country regions during the whole year. Leafy vegetable, being perishable, are grown locally. Traders have different relations with producers in different regions. They sometimes provide financial support for farmers to grow specific crops when prices are high in the market. Local production constitutes a tangible share in local consumption where supply of some crops, such as potato, exceeded consumption in 2003. Other vegetables, such as eggplant and tomato, have small shares in consumption: 15% and 17%, respectively. Generally the vegetables cultivated area grows at higher rate than productivity. Khartoum grows 12% of the vegetables' cultivated area in Sudan. Wholesale monthly average prices showed significant variation for all vegetables in the study. Also, consumer monthly and yearly prices showed significant variations. UPA is not only important for urban population, it is also more important for rural people; either for those who come and work as farmers in urban areas, or for those who produce to the urban consumers to gain more income and improve their livelihoods.

Keywords: urban market, wholesale price, consumer prices, vegetable market

4.1. Introduction

The evident expansion of urban areas worldwide and rapid growth of urban population (BRYLD, 2003; PRAIN, 2006) put pressure on food demand. Vegetables' consumption is increasing with urbanization where social and dietary preferences are affected (MARIAME & GELMESA, 2006; REGMI & DYCK, 2001). In spite of the importance of vegetables for human nutrition and health (SALEHI ET AL., 2010), vegetable consumption is low in the developing countries in comparison to the international recommendation of 400 g capita^{-1} day^{-1} (WHO, 2003).

Growth of urban dwellers has led to an increase in the cultivated areas and production where inhabitants are seeking self-reliance in food (MOUGEOT, 1993). The contribution of urban production to demand varies among cities. MOUGEOT (1993) stated that "*Cities such as Kathmandu, Karachi, Singapore, Hong Kong, Shanghai and others in China produce between 25% and 85% of their supply in vegetables and fruits, some cities even manage to export products to other countries*".

Khartoum, the capital of Sudan is populated with about 13.5% of the country's population, growing at 4.2% annually and where, at 2008, about 81% of the city's population was urban (CBS, 2010; THOMPSON ET AL., 2010). Due to urbanization and growing population, Khartoum has become the main center for vegetable marketing in Sudan (EMAM, 2011). FAO (2010) showed that the average consumption in Sudan stands at about 112 g person^{-1} day^{-1} during 2005-07.

The extended suburbs are the key to urban farming in the city due to availability of agricultural land (ABDELGADIR, 2002; PEPALL, 1993). The urban and rural agglomeration has a complementary relationship where growth of vegetables demand in urban centres encourages the flow of food products from rural areas to the urban market (AJAIMI ET AL., 2005). Different types of vegetables such as leafy, root, bulb and fruits are grown in the country under different irrigation systems (AHMED & MOHAMED, 1997; MARIAME & GELMESA, 2006).

Markets are usually either supportive or risk sources for both rural and urban farmers with regard to food production. Being price takers, generally vegetable producers have concerns about market and price changes, because of crop sensitivity (BÄCKMAN & SUMELIUS, 2009). Profitability is generally considered as the main incentive for crop production among commercial farmers (BÄCKMAN & SUMELIUS, 2009; USAID, 2009).

Four questions were raised by this study; what are the main sources of vegetables in Shambat central market, Khartoum? What are the relationships and links between traders and producers to maintain supply to the urban market? How much is the level of self satisfaction of vegetables in Khartoum? And are vegetable wholesale and consumer nominal and real prices reflecting production seasonality?

The study hypothesis's are: (1) Khartoum is a market for urban and rural vegetable production; (2) Traders affect the supply of vegetables in urban markets through providing financial support;

(3) Khartoum State, with an extended cultivated area, is still experiencing a gap in vegetable demand and (4) Vegetable prices face seasonal movements.

The objectives of this study are to identify different sources for vegetables flow to the urban market; to identify the relationship between traders and vegetable producers inside and outside Khartoum; to explore Khartoum's self-sufficiency rate in vegetables; and to investigate the trend in vegetable wholesale and consumer prices.

4.1.1. Theoretical framework on vegetable markets in Khartoum, Sudan

One of the major problems facing vegetable growers is price fluctuations (Figure 4.1). Food prices are mostly subjected to the powers of supply and demand (BÄCKMAN & SUMELIUS, 2009; CASAVANT ET AL., 1999; USAID, 2009). Furthermore, the rapid population growth and growing awareness of the nutritional and health value of vegetables lead to growth in demand in the developing countries (CASAVANT ET AL., 1999). Other factors affecting demand as for instance are; incomes of consumers, taste and preferences, and price and availability of substitute crops (CASAVANT ET AL., 1999).

Different factors influence food supply such as seasonality of production, input markets, government policies, crop price lag, flow of product from rural areas, and storage facilities (DOGONDAJI, 2007). Seasonality of agricultural production is reflected in the quantity supplied, which is true for vegetables even during a year and leads to price fluctuation (DOGONDAJI, 2007). Other factors also affect the supply as vegetables are being highly perishable with a short shelf life (FONSAH, 2003) which leads to appreciable losses of products (MARIAME & GELMESA, 2006). Moreover, fluctuations in quantity and price are dependent on the slope or elasticity of demand and supply (CASAVANT, 1999; JOHNSON & PLOTT, 1989). BÄCKMAN & SUMELIUS (2009) and STAGE ET AL. (2010) indicated that the supply of particular crops can vary due to local agricultural circumstances, as well as policies and institutional matters such as land property and credit availability, which are important for well functioning agriculture. SHONKWILER (1982) concluded that farmers respond to the lagged prices to decide which crop to grow in the current season. He also stated that "*the current and lagged price are negatively related*" which means that sometimes the decision is not a rational one. In the same context, JOHNSON & PLOTT (1989) stated that "*The cobweb model predicts that when supply decisions depend on this expectation, both price and quantity fluctuations result*" with indication to the lagged price (ELRASHEED & AWAD, 2009). Crop diversification and off-season crop production are risk aversion tools that are being used by farmers.

Changes of input prices, such as fertilizers, seeds, and irrigation, beside population growth and annual weather variations create variability in crops and price fluctuations. Annual weather variations in temperature, rainfall ... etc., and floods, are more important to the farmers because of their limited possibilities to adapt to changes in the short term (BÄCKMAN & SUMELIUS, 2009).

The marketing process is complicated and differs by crops and production areas. To improve crop flows, dealers created links with producers (EMAM, 2011). Dealers provide informal loans to farmers for specific crops; inside the city or in the other country regions. GREIG (2009) indicated that financial factors have effect on the crop choice, especially among commercial farmers. GREIG (2009) and KOMAREK (2010) indicated that the level of access to credit has effects on the crops grown where traders can intervene through provision of capital. Eventually, this affects farmers' returns and crop choice.

Vegetable markets are not subjected to governmental interventions as the case with cereals and other produce, because of the product's short shelf life and sensitivity. They also lack governmental support in terms of provision of market infrastructures, supportive policies and marketing information, which could support small farmers (ABDELGADIR, 2002). Other factors, such as real-price changes and price inflation[1] could affect price levels over time (CWIK, 2004; USAID, 2009). Prices could be adjusted for inflation to study the real change. If the adjusted prices showed no significant variation then prices are almost the same over time (USAID, 2009). Because prices affect both producers and consumers, the question will be on the changes in inputs prices and consumers' income. If the trend of input prices and consumers' incomes in the long term does not follow the trend of food prices, the demand and production will be affected.

[1] The definition of the term "inflation" has changed over time. The original usage meant an increase in the money supply (the cause), whereas its current usage denotes the increase in the general price level (the effect) (as stated in CWIK (2004)).

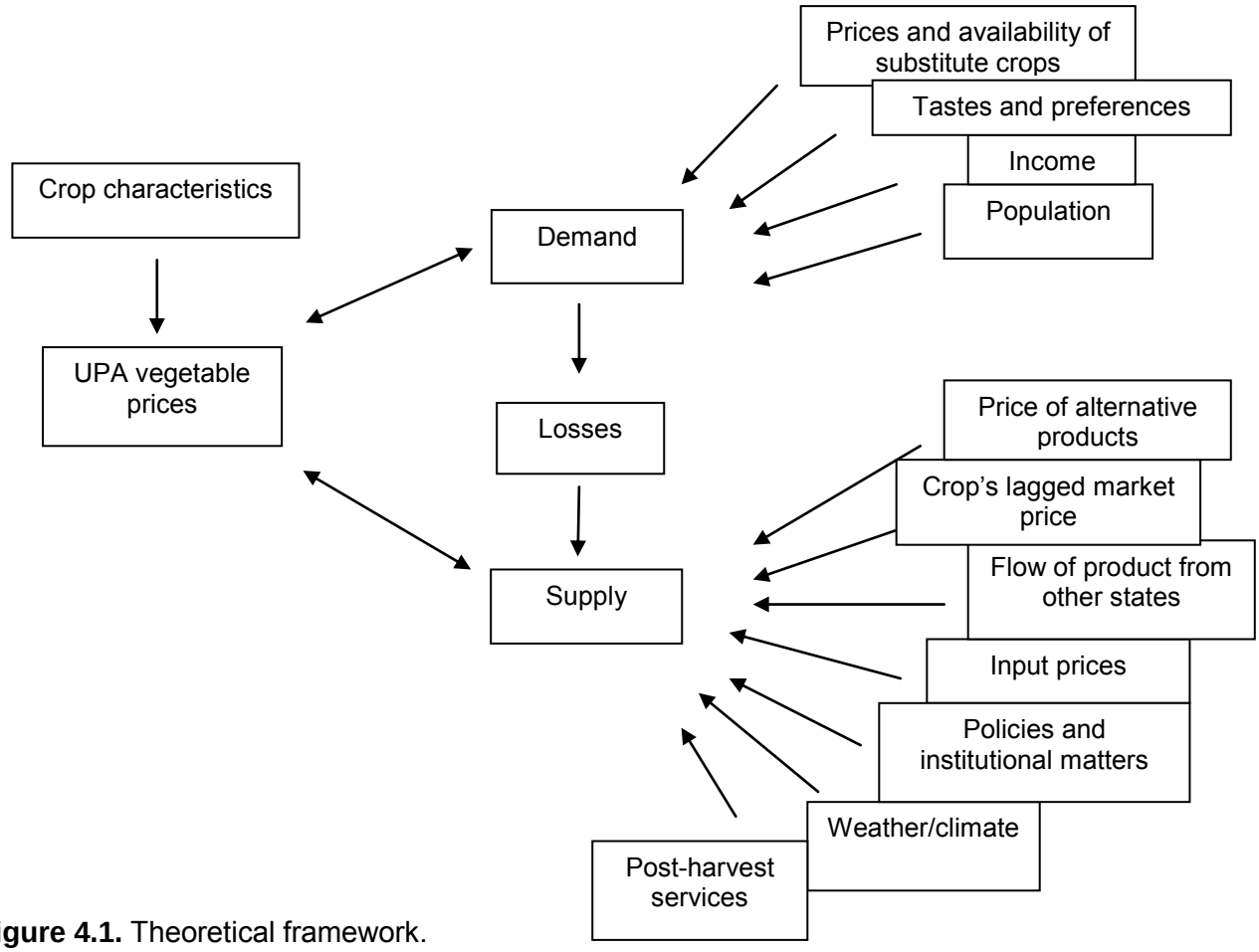

Figure 4.1. Theoretical framework.

Source: Own illustration based on CASAVANT ET AL. (1999) and OLSON (2004).

4.2. Research methods

Khartoum State constitutes three governorates, Khartoum, Khartoum North, and Omdurman. A survey conducted by the Khartoum state Ministry of Agriculture 2006 indicated that the bulk of the cultivated area is located in Khartoum North (Khartoum Bahry), with about 51% in comparison to the other two governorates (KHARTOUM STATE MINISTRY OF AGRICULTURE AND FORESTRY, 2006; THOMPSON ET AL., 2010). A central market is located in each governorate (EMAM, 2011) where products coming from different country regions. For this study Shambat central market was chosen because of its location in Khartoum North.

Primary and secondary data were used to attain the objectives. Primary data collection and informal interviews were conducted in the market. Wholesale vegetable prices for about 20 vegetable crops were collected for one year on weekly basis, starting from February 2009 to January 2010. Different types of vegetables were targeted such as leafy, root, bulb, and fruity vegetables. At least three traders were interviewed for each crop during the weekly visits depending on the availability of the product in the market. The prices were collected for the sales units that are commonly used in the market. After that sales units were weighed (in kg) in the market and the average weight was used to calculate the price per kg. Then monthly average prices were calculated.

Few vegetable wholesale traders, 8-10, were informally interviewed individually during April 2010 to trace sources of vegetables, access to products, relationship with farmers and marketing channels for vegetables from producers to retailers, and factors affecting vegetable market prices. At least one trader for each crop was talked to where some traders are dealing with more than one crop. Also, during the weekly visit, traders were asked to explain the reasons whenever price changes were witnessed; whether increases or decreases.

Besides, time-series data, from January 1998 to October 2006, for consumer prices of some vegetables in Khartoum state was gathered from the Central Bureau of Statistics. Average monthly prices were used to investigate price trends. Nominal prices[2] were adjusted for inflation to derive real prices using Consumer Price Index (CPI) (KOKOSKI, 2010; USAID, 2009). Khartoum monthly CPI was used in the calculation, from January 1998 to October 2006. For this study the real prices (RP) were calculated using CPI of January 1998 with base year January 1992.

$$RP_{cy} = \frac{CPI_{by}}{CPI_{cy}} \times NP_{cy}$$

Where

CPI is Consumer Price Index;

by is Base year = January 1998;

cy is Current year = on monthly basis from January 1998 to October 2006; and

NP is Nominal price = prices observed on the market.

Secondary data was collected from related sources, Directorates of the ministries of agriculture, to identify the status of potential production of vegetables in Sudan and Khartoum and to estimate vegetable consumption in Khartoum. Also a formal survey was conducted for intra- and peri-urban farmers in 2007 where a semi-structured questionnaire was used to collect information about farmer's interaction with market and changes in urban vegetable market criteria from the farmer's point of view from 1990 to 2007.

Descriptive analysis such as graphs and/ or plotted time-series data, at monthly intervals, was used to illustrate price trends according to the specified objectives. Price stability and fluctuations were determined subject to the numbers of occurrence of peaks in the price line through time. Nonparametric analysis, Kruskal-Wallis test, and parametric, one-way ANOVA were used to investigate the significance of price variations from year to year and between months (SPSS Inc., 2004).

[2] Nominal price is equal to the money that paid for a unit of good or service in the market, at the shop, etc. these are prices observed on the market (Defined by USAID, 2009).

4.3. Results

Shambat central market in Khartoum North is open 7 days a week. Vegetables and fruits are brought to the central market by dealers[3], wholesale[4] traders, and farmers from different areas within the city or from the periphery and other rural areas. Deals are mainly done by middlemen, traders (wholesalers and retailers), and farmers who used to work during their leisure time to improve their incomes (Figure 4.2). The wholesalers are men while retailers are men and women. Some of the retailers buy vegetables in cash and sell them for their own benefits. Others sell products belonging to wholesalers and then take their wage as percentage of the total return. The later method was observed mainly in leafy vegetables and tomato transactions. Some retailers buy vegetables and sell them in the city's internal small vegetable shops that are scattered within the city.

The survey conducted among UPA farmers showed that about 70% of the sampled farmers make deals by themselves in comparison to others who depend on cooperatives, partners or relatives. Products sales take place in the farm, along the road near the farm, or in the market. Out of 72 vegetable farmers interviewed, about 25% sell vegetables in the farm, 35% sell in the market, and 40% sell in both farm and market.

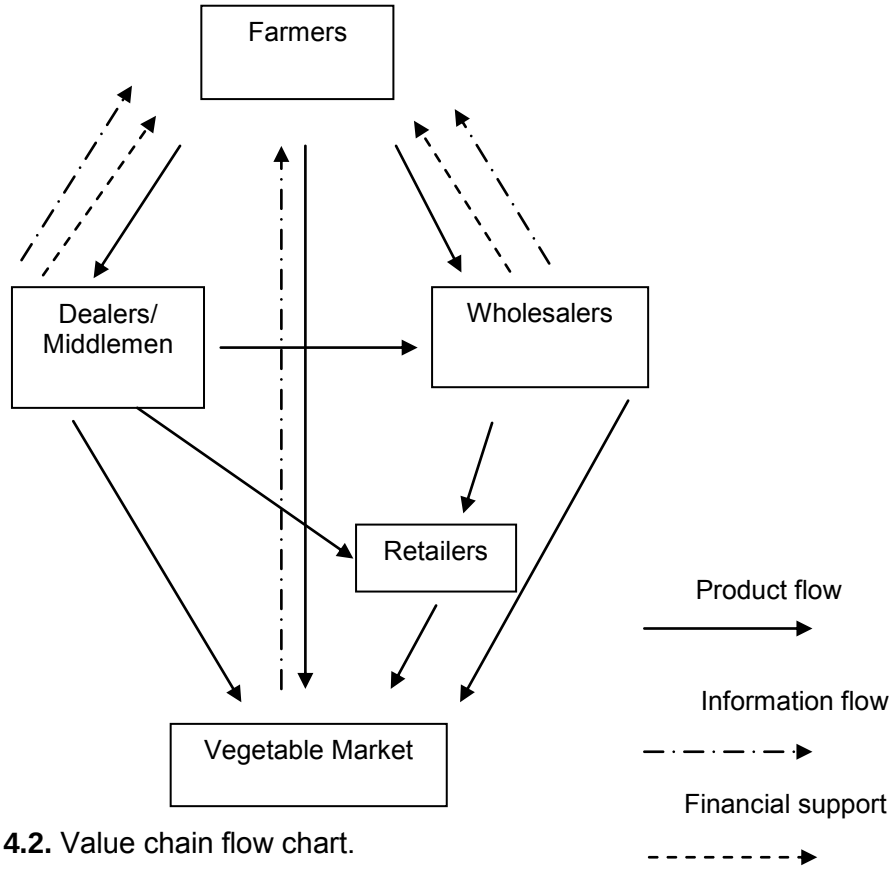

Figure 4.2. Value chain flow chart.

Source: Own illustration.

[3] Dealers (middlemen) are usually the traders who finance the farmer to grow specific crops and bring it to the market for the wholesaler.

[4] Wholesaler is the trader who is available in the market and sells in large quantities.

Before 20 years, as mentioned by farmers, supply depended on local production, which reduced losses and competition via production from other regions. Nowadays producers from other country regions, due to high demand in Khartoum state, target the off-season in Khartoum where the internal supply is low and prices are relatively high (as indicated by vegetable traders in the market). The new technologies, mobile phones, speed the diffusion of information where traders in the other country's regions keep in contact and follow the market price movements.

Vegetable traders were asked about the sources of vegetables entering Shambat central market and results are shown in Table 4.1 and Figure 4.3. Northern and River Nile states produce red and white onion, carrot, pumpkin, hot pepper, sweet pepper, gherkin, potato and tomato. Central states produce tomato, carrot, okra, red onion, eggplant, squash, hot pepper, and cucumber. Eastern states produce pumpkin, white onion, red onion, and squash. South Kordofan state produces pumpkin. Southern state (Upper Nile state) produces only tomato (Figure 4.3).

According to official statistics, Sudan has a great potential in vegetable production where production exceeds consumption. Figure 4.4 shows that Sudan is self-sufficient in vegetable production and the country witnessed abundance in their production in recent years. The country witnessed yearly post-harvest vegetable losses ranging from 20% to 67% of consumption.

Vegetables' cultivated area and production in Sudan showed an increasing trend between 2000 and 2004 (Table 4.2). The growth of cultivated area varied among vegetable types. At the same time, growth of production is not the same as that of the area. Production growth rate ranged between 4% and 36% while the area growth rate ranged between 8% and 50%. Spices, eggplant, and sweet potato areas increased by almost 50% of the previously cultivated area. Spices, onion, tomato, and cucurbits occupied most of the newly cultivated areas; about 68%.

Table 4.3 shows that Khartoum accounted for about 12% of the vegetables' cultivated area in the country during 2003. Various vegetables are cultivated in Khartoum where okra, potato, onion, and cucurbits have an estimated share of 74% of the area grown with vegetables. Foliage crops use about 3% of cultivated area in Khartoum and that area is estimated at about 14% of the total foliage cultivated area in Sudan. Khartoum share in total crop production varied among vegetables where spices and onions showed higher potential productivity while others like cucurbits and okra showed lower potential yield.

Table 4.4 shows per capita year^{-1} consumption of some vegetables in Khartoum. Onions and tomatoes have the greatest share followed by other vegetables. The average per capita consumption is estimated at about 98 kg year^{-1}. Self-sufficiency ratio varied among vegetables where potato production is in abundance while other vegetables are in shortage. Table 4.4 indicated that self-sufficiency in vegetables in Khartoum is about 56% during 2003, where the gap is filled by products from other rural areas and imports, as mentioned by traders.

Table 4.1. Origins of vegetable crops supply in Shambat central market as mentioned by interviewed traders during February 2009 to January 2010.

Crops	States/ cities	Source Intra and peri-urban Khartoum
Red onion	Northern, River Nile, Gezira, and Kasala states	Gari, Al-khelaila
White onion	Kasala, and Northern states	
Tomato	Renk, Damazin, Sennar, Gezira, New halfa, Kosti, Al-zaidab, Hajer al-asal	Al-gaily, Wadramli, Al-seleit
Eggplant	Gezira, Sennar, Hajer al-asal	Al-ailafoon, Al-gaily, Al-izairgab, Al-khelaila
Cucumber	Al-fao, Gezira state	
Carrot	Gezira state, Atbara	Al-gaily, Wadramli
Potato	River Nile, Northern, New Halfa	Al-shihainab, Wadramli
Sweet potato	Gezira state	Al-seleit
Pumpkin	Gedarif, Damazin, Kasala, Wad-hamid, Al-basabir, Abu gibaiha, Al-hawata	Wadramli, Al-gaily
Okra	Kosti	Gamoeia, Al-ailafoon, Al-seleit
Hot pepper	Gezira state, Hajer al-asal	Al-ailafoon
Sweet pepper	Hajer al-asal	Faki Hashim, Al-khojalab, Khartoum north
Squash	Kosti, Damazin, Gezira state	Al-gaily, Al-izairgab, Al-halfaia,
Gherkin	Northern state	Al-gaily, Soba-east, Wawisi
Cabbage*		Al-khojalab, Faki Hashim, Karari
Cauliflower		Al-khojalab, Faki Hashim, Karari
Green onion		Gari, Al-gaily
Green bean		Khartoum, Al-seleit
Rocket cress, Jew's mallow, Purslane, & Radish		Intra-urban areas around the River Nile

Source: informal interview with traders in Shambat central market, 2010.
* Part of supply came from Ethiopia and Eritrea.

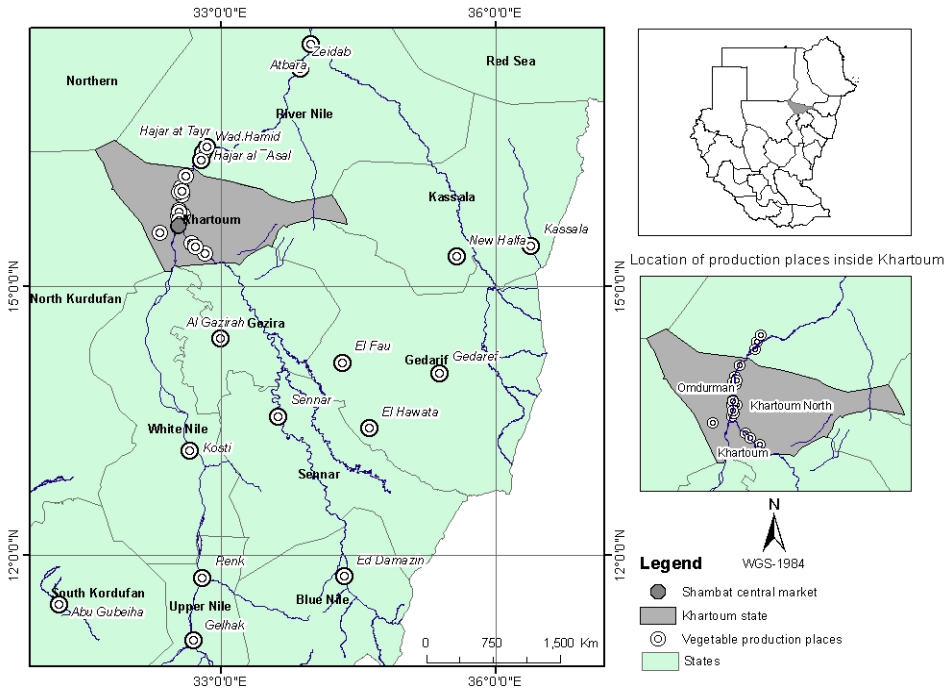

Figure 4.3. Location of the study area. The white double circles indicate the locations of vegetable production inside and outside Khartoum state, that supply Khartoum markets, as indicated by traders in Shambat central market, February 2009 to January 2010.

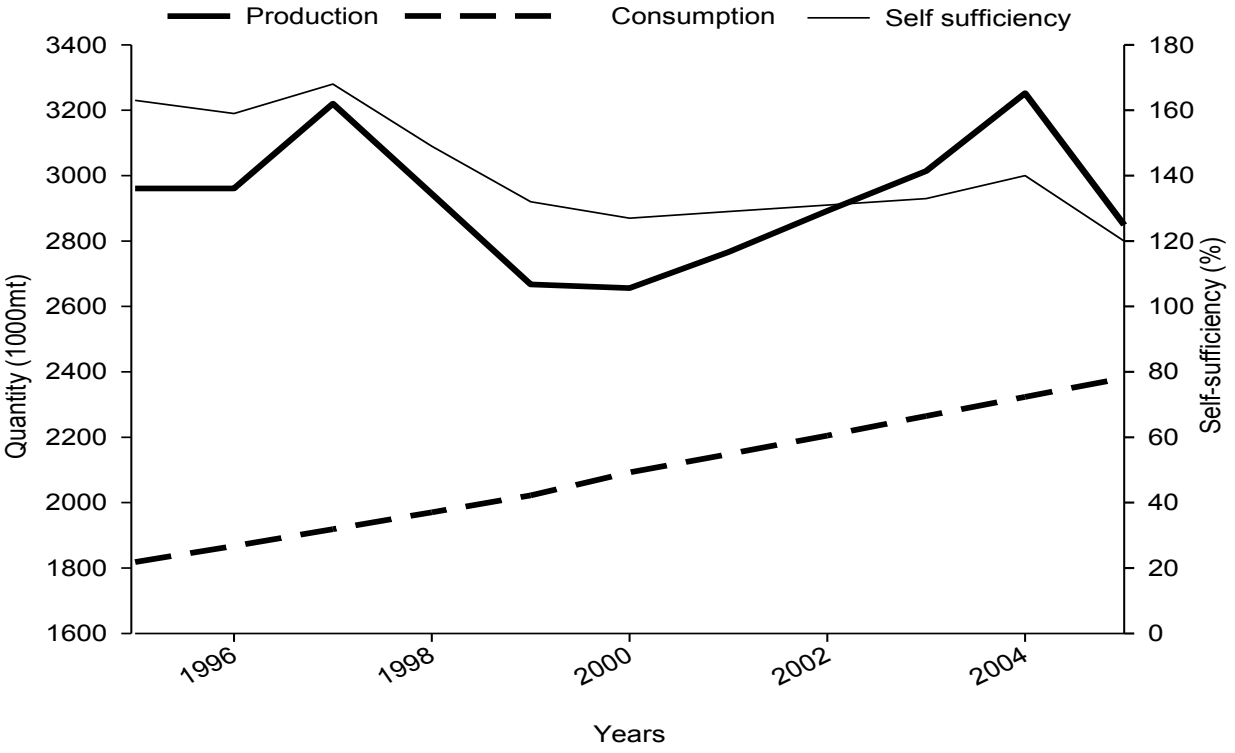

Figure 4.4. Vegetable production and consumption (000mt) and self-sufficiency rate during the period 1995 to 2005 in Sudan.

Table 4.2. Vegetables' cultivated area (000ha) and production (000ton), 2000 - 2004 in Sudan.

Year	2000		2001		2002		2003		2004		% Growth*	
Crop	Cultivated area	Production	Cultivated area	Production	Cultivated area	Production	Cultivated area	Production	Cultivated area	Production	Cultivated area	Production
Onion	45.8	872	47.4	904	47.9	912	49.4	971	53.4	1016	16.5	16.5
Tomato	31.7	456	31.8	455	31.9	456	32.8	423	38.9	556	22.9	21.9
Egg plant	2.6	45	2.6	44	2.7	45	2.9	48	3.7	61	40.3	35.6
Okra	18.9	212	20.2	182	22.3	212	24.4	241	25.2	252	33.3	18.9
Spices	21.8	122	27.3	117	28.6	122	30.6	137	32.8	140	50.0	14.8
Cucurbits	31.1	588	32.8	546	35.3	588	37.5	607	38.7	644	24.3	9.5
Potato	16.4	300	17.2	287	18.0	300	18.6	301	20.2	336	23.1	12.0
Foliage vegetable	4.5	53	4.6	51	4.7	53	4.8	54	5.0	55	9.3	3.8
Sweet potato	7.9	136	7.9	132	8.2	136	8.4	136	11.4	141	44.9	3.7
Others	4.6	49	4.7	48	4.7	49	4.8	50	5.0	51	8.3	4.1
Total	185.3	2833	196.6	2766	204.2	2873	214.1	2968	234.1	3252	26.3	14.8

Source: Directorate of Horticultural sector, Federal Ministry of Agriculture.
Others include: Sweet pepper, Green beans, Pea, Carrot, Sugar beet, Gherkin, Melon, Cabbage, Cauliflower, and Lettuce. This cultivated in Khartoum, River Nile and Gezira states.
* % Growth from 2000 to 2004.

Table 4.3. Estimates of vegetables' cultivated areas (ha) and production (mt) in Khartoum and Sudan, 2003.

	Khartoum		Sudan		Khartoum share	
Crop	Area	Production	Area	Production	% Area	% Production
Onion	5775	105829	49343	714141	11.7	14.8
Tomato	1678	24363	32804	423274	5.1	5.8
Okra	5325	27029	24376	205375	21.8	13.2
Egg plant	279	3724	2871	47826	9.7	7.8
Potato	3667	59350	18552	300108	19.8	19.8
Cucurbits	3956	19774	37509	607080	10.5	3.3
Spices	802	13356	30593	136822	2.6	9.8
Foliage crops	685	3258	4800	53890	14.3	6.0
Sweet potato	298	3261	8675	122166	3.4	2.7
Others	2904	27648	4832	49653	60.1	55.7
Total	25369	287592	214355	2660335	11.8	10.8

Source: Directorate of Agricultural Statistics, Federal Ministry of Agriculture.
Others include: Sweet pepper, Green beans, Pea, Carrot, Sugar beet, Gherkin, Melon, Cabbage, Cauliflower, and Lettuce. This cultivated in Khartoum, River Nile and Gezira states.

Table 4.4. Annual per-capita consumption of some vegetable items (in kg), total consumption* (mt), production (mt), and self sufficiency ratio in Khartoum state, 2003.

Crops	Consumption (kg capita^{-1} y^{-1})	Consumption (mt)	Production (mt)	% Self sufficiency
Onion	32.6	171361	105829	61.8
Garlic	3.7			
Jew's mallow	4.8			
Cucumber	2.2			
Okra	5.8	30488	27029	88.7
Green peas	0.9			
Tomato	30.2	158745	24363	15.3
Egg plant	4.1	21552	3724	17.3
Green pepper	1.6			
Tomato paste	2.9			
Canned vegetable	1.0			
Potato	7.2	37847	59350	156.8
Other Tubers	1.1	5782	3261	56.4
Total	98.1	515660	287592	56.0

Source: consumption (kg capita^{-1} y^{-1}) adapted from (Ajimi, 2005) and production (mt) data from Khartoum State Ministry of Agriculture reports.
* Consumption for total population calculated using estimated population size in Sudan for 2003.

4.3.1. Analysis of wholesale prices

Wholesale prices of different types of vegetables were collected on weekly basis from Shambat central market. Price trends were analyzed, using graphs, and discussed below for each type of vegetables. Nonparametric test (Kruskal-Wallis test) was used to investigate the variation in monthly wholesale prices (Table 4.5).

Table 4.5. Average yearly wholesale price (SDG/kg) and Kruskal-Wallis test for monthly prices for vegetable crops in Shambat central market February 2009 – January 2010 in Khartoum, Sudan.

Crop	Price (SDG/kg) All data mean (std)	Price (USD$/kg) All data mean (std)	Kruskal Wallis test x^2	N
Jew's mallow	0.51 (0.20)	0.22 (0.09)	29.49**	51
Rocket cress	0.58 (0.33)	0.24 (0.14)	26.26**	50
Chard	0.45 (0.20)	0.2 (0.08)	27.47**	50
Cowpea	0.64 (0.15)	0.27 (0.07)	18.32	44
Purslane	0.30 (0.13)	0.12 (0.05)	16.00	51
Carrot	0.75 (0.25)	0.31 (0.10)	39.65***	51
Radish	0.52 (0.13)	0.22 (0.05)	33.11**	48
Tomato	3.56 (2.30)	1.5 (0.93)	36.60***	50
Red onion	1.20 (0.48)	0.51 (0.21)	46.38***	50
White onion	1.03 (0.65)	0.44 (0.28)	38.73***	43
Green Onion	0.55 (0.20)	0.23 (0.08)	31.33***	42
Cucumber	0.87 (0.49)	0.36 (0.20)	25.53**	50
Eggplant	1.20 (0.73)	0.502 (0.30)	36.03***	49
Okra	2.10 (0.64)	0.88 (0.27)	26.57**	51
Gherkin	2.30 (1.30)	0.97 (0.54)	29.06**	45
Sweet pepper	1.80 (0.87)	0.76 (0.36)	30.93**	50
Hot pepper	2.28 (1.35)	0.97 (0.54)	29.45**	46
Pumpkin§	3428.20 (1330.50)	1442.4 (546.13)	37.73***	48
Squash	1.40 (0.75)	0.59 (0.31)	13.63*	20
Potato	2.84 (0.88)	1.2 (0.37)	37.75***	49
Sweet potato	0.99 (0.26)	0.42 (0.11)	41.81***	49

§ Price is SDG lorry^{-1} weighted around 4 ton.
* $p < .05$, ** $p < .01$, *** $p < .001$.
1 SDG (New Sudanese Pound) ≈ 0.4 USD $.

4.3.1.1. Leafy vegetables

Leafy vegetables that are cultivated in the intra-urban areas are mainly Jew's mallow, rocket cress, purslane, cowpea, and chard. Other leafy vegetables as lettuce, cabbage, cauliflower, and spinach are cultivated in the peri-urban area and only available, from the local source, for few months during the year.

Due to being highly perishable, leafy vegetables are mainly produced around the city center, near market areas, with some small fragmented areas in the peri-urban suburbs, while sizable amounts of other vegetables supply come from other regions.

Usually dealers buy the crops at harvesting stage. They agree on the price and then traders undertake the harvest process. They harvest the crop according to the market price with possibility of delaying crop harvesting. Some dealers and wholesale traders provide financial support, in terms of cash and/or kind (inputs), to the farmers to cultivate specific crops,

especially when supply is short and market price is high. If price stays high at harvest time, the farmer and dealer together decide on the selling price. Then the trader decides whether he will buy the product or not. In the latter case the farmer needs to pay pack the amount of cash received from the trader. On the other hand some dealers buy the newly grown crop, at the shoot stage. In this case the farmer works on crop irrigation while fertilizers and pesticides can be add by the trader.

In the market, traders sell products to the retailers. Some of the retailers buy the product and then sell it at own expenses. Others sell for the benefit of the trader, as in the case of rocket cress sold by women who get part of the proceeds; between 5% and 10% after selling the product. The share value depends on how much returns are earned.

Some leafy vegetables are grown inter-exchangeable where in most cases Jew's mallow is grown during summer and purslane during winter, with few exceptions of off-season cultivation. On the other hand, rocket cress is grown throughout the whole year.

Lettuce appeared in the market during winter; from December and remains available until June. Newly introduced vegetables, such as cabbage and cauliflower, are cultivated in the peri-urban areas near Nile River, and local production is available in the market during winter while that brought from Ethiopia and Eritrea comes during the off-season.

Prices of leafy vegetables showed fluctuations during the year (Figure 4.5a), Jew's mallow and cowpea prices were volatile with 3 peaks, while prices of other leafy vegetables showed only two peaks. During flood season, from end of July to mid September, parts of the intra-urban areas are flooded with river water and cannot be cultivated. The price of leafy crops shows remarkable peaks during September and October as a result of supply shortage. Nevertheless, prices of rocket cress are stable while other vegetables witnessed fluctuations during the year (Figure 4.5a). Monthly prices significantly differ among leafy vegetables (x^2= 29.49**), (x^2= 26.26**), (x^2= 27.47**) and (x^2= 18.32*) for Jew's mallow, Rocket cress, chard and cowpea, respectively. Only purslane prices didn't showed significance differences (Table 4.5).

4.3.1.2. Root vegetables

The main root crop that is cultivated in the Intra-urban areas is radish, which is also cultivated in the peri-urban area. Carrot is cultivated in the peri-urban areas around Khartoum, such as Al-gaily and Wadramli, and also considerable quantities came from the nearest states such as Gezira and River Nile.

Some of the traders deal with the farmers through providing loans to cover production cost and hence, at harvest time, they get the best deal. One of the traders mentioned that he used to rent a piece of land every year in the Gezira area to be grown with carrot.

The root vegetables have relatively longer shelf life in comparison to the leafy ones and that gives a better price stability with one or two peaks. Radish prices start to increase from

February to September, showing a peak during September because of flood time, and then start to decrease. While carrot reached its highest price during August and September and then starts to decline (Figure 4.5b). Monthly prices are significantly different (x^2= 33.11**) and (x^2= 39.65***) for radish and carrot, respectively (Table 4.5).

4.3.1.3 Fruit vegetables

The fruit vegetables shelf life varied among vegetables types. Tomato comes from upper Nile state (Renk and El-galhak), especially during the off-season, and from River Nile, Gezira, Blue Nile, Sennar, and Kasala states. The peri-urban areas in Khartoum contributing to tomato supply are mainly Al-gaily, Wadramli and Al-seleit scheme and are all located in Khartoum North. Some of the farmers and/or dealers target the off-season to get high return. As stated by dealers, they support farmers in the other states to produce off-season tomato, with relatively higher costs, for urban market.

Tomato is highly perishable and its prices are very fluctuating, with three peaks, especially during the main production season, winter. On the other hand, its price increases during the off-season due to supply shortage. Figure 4.5c shows three peaks at June, September, and November. Tomato monthly prices are significantly different (x^2 = 36.60***) (Table 4.5).

Onion is available in three different varieties (varietals forms): dry red, white, and green onion. As indicated by traders, appreciable quantities of red onion originate mainly from other regions such as River Nile, Gezira, Kassala, and Northern states. White onion originates from Kassala and River Nile. Some locations in the peri-urban areas in Khartoum North such as Al-khelaila, Al-gaily and Gari produce green and red onion.

Prices of green onion (Figure 4.5d) showed stability. Prices started to rise in July, reached their peak in September and then started to decline. During August, green onion was not available in the market but showed up during September at high price. Prices of red and white onions fluctuated throughout the year, reached their highest peak during November and December and then started to decrease in January. Supply quantities flowing from different areas affect the price to a greater extent with regard to different varieties (Figure 4.5d). Onion's monthly prices showed significant differences (x^2 = 46.38***), (x^2 = 38.73***) and (x^2 = 31.33***) for red, white and green onion, respectively (Table 4.5).

Cucumber prices witnessed two peak points; in August and November (Figure 4.5e). Cucumber originates from eastern part of Sudan and Gezira state. Interviewed traders indicated that a shortage in supply normally raise the prices. Usually during "Ramadan", which was around August and September in 2009, the product witnessed high demand and that increased the price (Figure 4.5e). Monthly prices varied significantly (x^2 = 25.53**) (Table 4.5).

Eggplant has one peak point during June and then prices decreased up to January. Eggplant originates from Gezira, Sennar, River Nile states and from around Khartoum North such as Al-gaily, Al-ailafoon, Al-izairgab and Al-khelaila. Prices of eggplant started to go up from

March, reached their peak in June and then declined (Figure 4.5e). Monthly prices showed significant differences (x^2 = 36.03***) (Table 4.5).

Okra mainly originates from the peri-urban areas such as Gamoeia scheme, Al-Seleit scheme, Al-ailafoon and Soba, as well as from other regions such as White Nile (Kosti). Okra prices started to increase in April, reached their highest price in July and August, during rainfall season, then declined thereafter, but rose in November and continued to decline again. Okra prices showed relative stability with two peaks. They reached their highest peak in July and August due to seasonal increase in demand which coincided with the onset of "Ramadan" (Figure 4.5e). Okra monthly prices showed significant variation (x^2 = 26.57**) (Table 4.5).

Hot pepper is mainly brought from Gezira, and Hajer al-asal and Al-ailafoon around Khartoum, while sweet pepper is brought from Hajer al-asal, Faki Hashim and Al-khojalab in the peri-urban setting. Hot pepper price was volatile and witnessed three peaks, May, July and September. Sweet pepper prices showed two maximums: May to June and September to October (Figure 4.5f). Significant differences are depicted in monthly prices: (x^2 = 29.45***) and (x^2 =30.93**) for hot pepper and sweet pepper, respectively (Table 4.5).

A small supply of pumpkin came from Wadramli and Al-gaily areas within Khartoum territory (as mentioned by traders). Most of the quantities came from the eastern region, especially Gadarif state. June and July witnessed the highest prices for Pumpkin; otherwise prices were stable. Squash came mainly from Kosti, Damazin and Gezira areas while part of the supply came from Al-gaily and Al-izairgab within Khartoum boundary. Squash prices witnessed a high jump in May and then started decreasing until January; showing three peaks (Figure 4.5g). Monthly price of pumpkin and squash showed significant differences: (x^2= 37.73***) and (x^2= 13.63*), respectively (Table 4.5).

Some vegetables were only available during the winter season such as green bean, which was observed in two months: December 2009 and January 2010. Haricot bean prices started at high level and then began to decrease during January.

4.3.1.4 Bulb vegetables

Bulb vegetables like potato and sweet potato can be stored in refrigerators and at open place, respectively, which extends the crop season and improves prices. Farmers sell part of the production after harvesting, when prices are at their lowest level, to cover the cost of production, agricultural loans, and their daily expenditure. They used to store the rest to be sold later when the market prices rise or when they are in financial needs. Interviewed traders mentioned that the River Nile and Northern states' potato reaches the market earlier

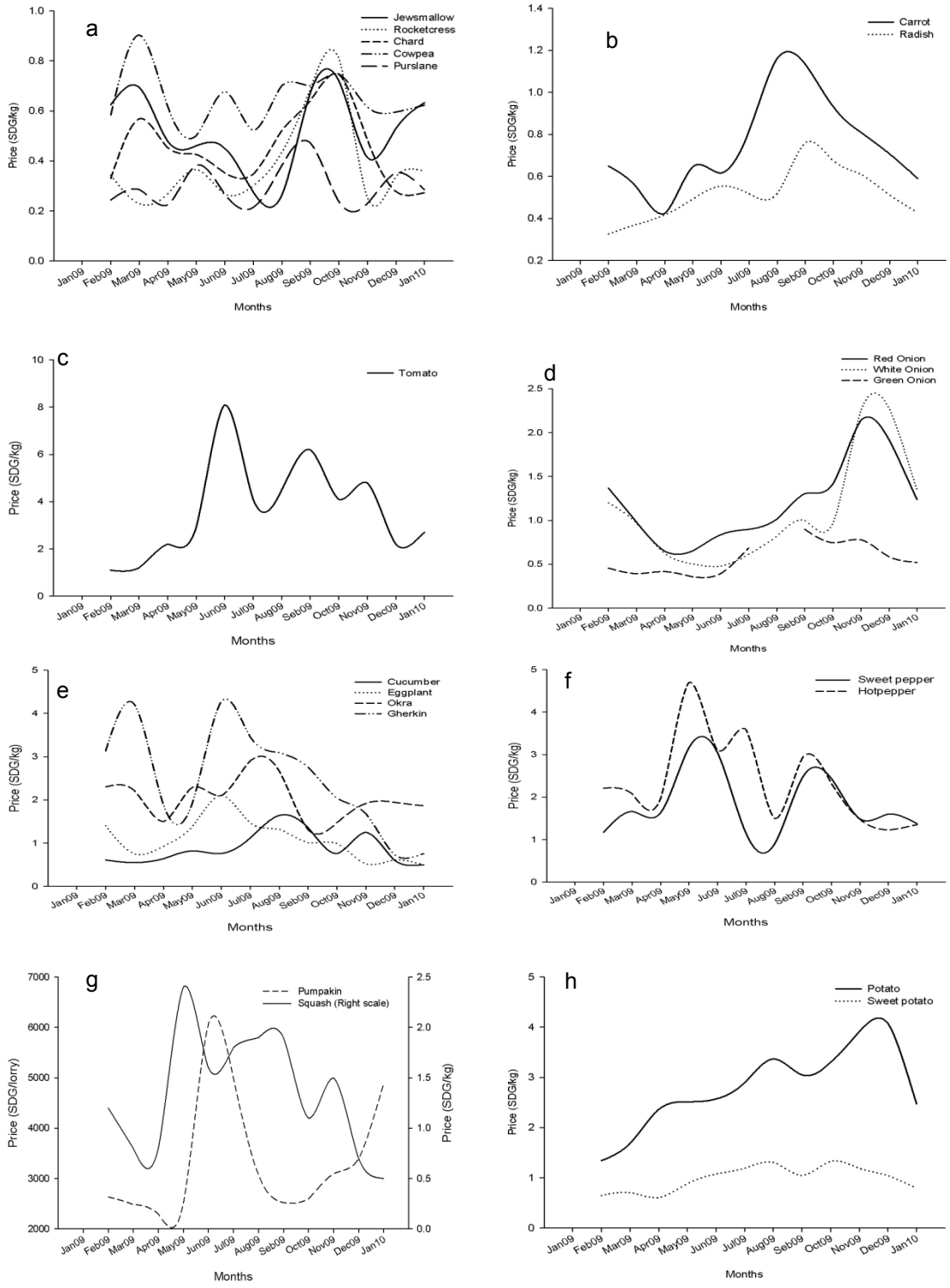

Figure 4.5. Wholesale prices of different vegetables in Shambat central market in SDG/kg from February 2009 to January 2010: a. leafy vegetables b. carrot & radish c. tomato d. Onion (red, white and green) e. cucumber, eggplant, okra and gherkin f. sweet pepper & hot pepper g. pumpkin & squash h. potato & sweet potato.

before Khartoum harvest. Sweet potato is cultivated in Al-seleit scheme and significant amounts came from Gezira state to fill the consumption gap.

Potato price depicted an increasing trend during 2009 until December and then started to decline due to the flow of supply from the River Nile state. Price of sweet potato was relatively stable compared to the price of potato. It started increasing in April until August, dropped in September, rose again in October and then started to decline (Figure 4.5h). Monthly prices are significantly variable: (x^2= 37.75***) and (x^2= 41.81***) for potato and sweet potato respectively (Table 4.5).

4.3.2. Analysis of consumer prices

The consumer prices for 12 vegetable crops were compiled and analyzed. Nominal and real prices were fluctuating from month to month. The one way ANOVA was used to test the variation of the yearly and monthly consumer prices. The *p* value showed high significant difference for vegetables' nominal prices between years for all crops except tomato (Table 4.6). Real prices also showed highly significant differences among years except onion, squash and tomato prices. When monthly nominal prices were tested, only onion, squash, tomato, and potato were significantly different. Real monthly prices for onion, Jew's mallow, squash, okra, tomato, and potato revealed highly significant variation (Table 4.7).

Table 4.6. One way ANOVA test for annual consumer, nominal and real, prices for the period January 1998 to October 2006 in Khartoum, Sudan.

Time	Variables	SS_B	df	MS_B	F
Year	Nominal price onion	65.226	8	8.153	6.456***
	Real price onion	8.885	8	1.111	1.824
	Nominal price Jew's mallow	2.291	8	0.286	13.467***
	Real price Jew's mallow	0.414	8	0.052	4.004***
	Nominal price spinach	25.702	8	3.213	25.417***
	Real price spinach	2.689	8	0.336	8.735***
	Nominal price purslane	4.123	8	0.515	38.488***
	Real price purslane	0.451	8	0.056	9.936***
	Nominal price squash	12.803	8	1.600	8.677***
	Real price squash	0.947	8	0.118	2.023
	Nominal price pumpkin	10.621	8	1.328	34.4***
	Real price pumpkin	0.807	8	0.101	9.505***
	Nominal price okra	55.433	8	6.929	31.394***
	Real price okra	8.486	8	1.061	09.812***
	Nominal price eggplant	18.526	8	2.316	44.608***
	Real price eggplant	2.009	8	0.251	19.222***
	Nominal price tomato	25.874	8	3.234	2.203*
	Real price tomato	7.054	8	0.882	1.621
	Nominal price cucumber	3.306	8	0.413	7.465***
	Real price cucumber	0.577	8	0.072	4.116***
	Nominal price potato	34.727	8	4.341	20.316***
	Real price potato	4.829	8	0.604	6.358***
	Nominal price sweet potato	3.629	8	0.454	8.554***
	Real price sweet potato	0.398	8	0.050	17.443***

B = between groups.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Table 4.7. One way ANOVA test for monthly Consumer, nominal and real, prices for the period January 1998 to October 2006 in Khartoum, Sudan.

Time	Variables	SS_B	df	MSE_B	F
Months	Nominal price onion	77.378	11	7.034	5.992***
	Real price onion	38.297	11	3.482	11.04***
	Nominal price Jew's mallow	0.772	11	0.07	1.841
	Real price Jew's mallow	0.7	11	0.064	6.173***
	Nominal price squash	9.379	11	0.853	3.76***
	Real price squash	2.543	11	0.231	5.329***
	Nominal price okra	9.44	11	0.858	1.197
	Real price okra	4.64	11	0.422	2.767**
	Nominal price tomato	121.711	11	11.065	22.322***
	Real price tomato	44.803	11	4.073	25.501***
	Nominal price potato	10.845	11	0.986	2.078*
	Real price potato	4.923	11	0.448	4.615***

B = between groups.
* $p < .05$, ** $p < .01$, *** $p < .001$.

Figure 4.6 showed seasonal movements of monthly nominal and real prices for purslane, onion, tomato, and potato. The rate of price fluctuation varied between crops. Price movement for each crop showed same yearly trend with some exceptions. The 1998 real price was higher in level than those of 2000 and 2002 for purslane, onion, and potato, especially for the second part of the year. The nominal and real prices for potato were higher in 1999 than in the following years from March to December. The tomato 2005 prices were high in absolute terms.

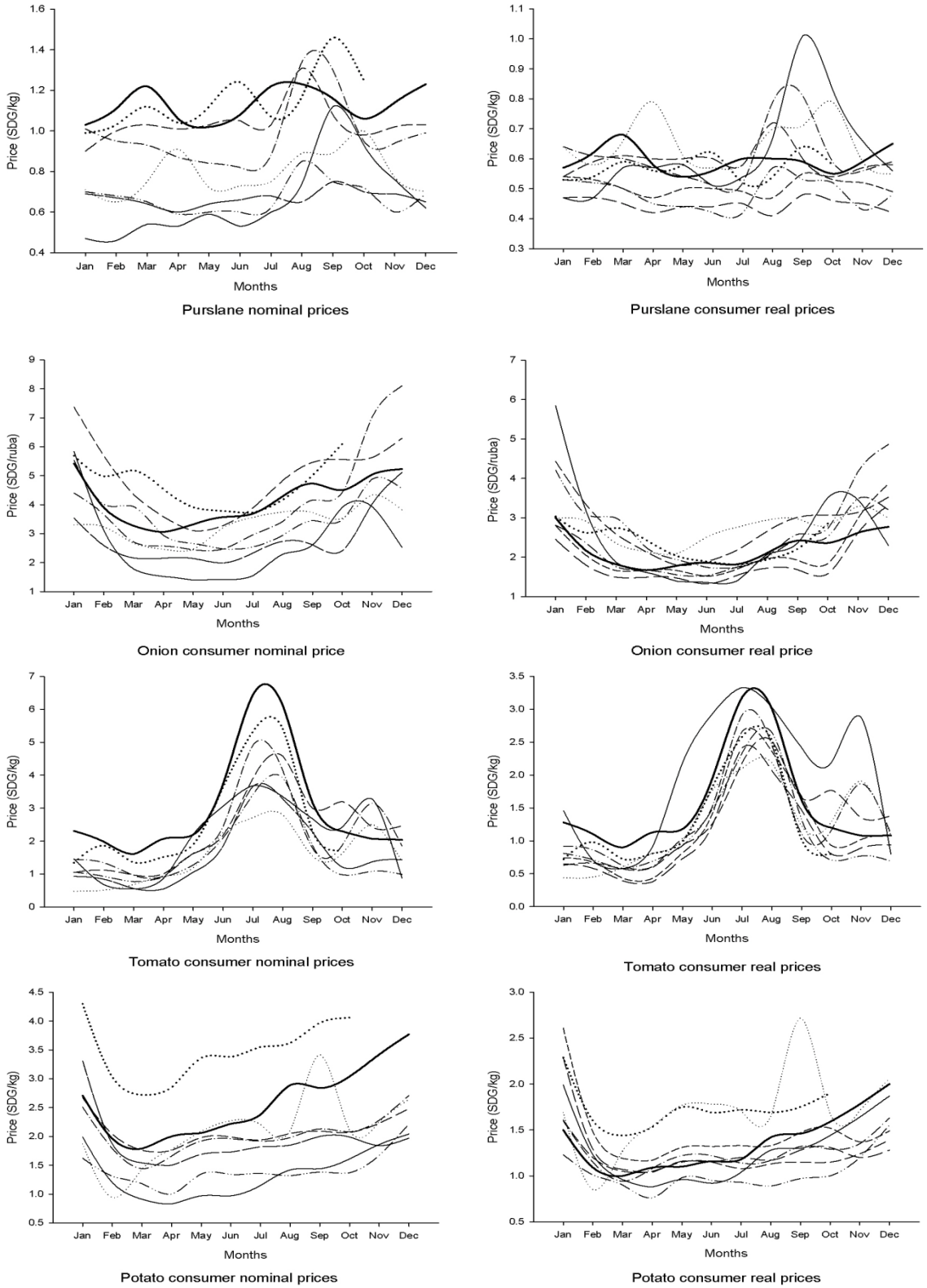

Figure 4.6. Consumer monthly nominal and real prices (SDG/kg) for purslane, tomato, and potato, and onion (SDG/ruba) for the period 1998 to 2006.

4.4. Discussion

Unpredictable and fluctuating market prices (CASAVANT ET AL., 1999), which characterize vegetable prices, are great hindrance to vegetable production in Khartoum and other states (THOMPSON ET AL., 2010). Farmers are market-oriented and market prices are of great importance to crop cultivation (GREIG, 2009), especially to fast growing crops like leafy vegetables, which dominated the intra-urban production, (THOMPSON ET AL., 2010).

The agricultural supply of particular crops can vary due to agricultural circumstances (BÄCKMAN & SUMELIUS, 2009; STAGE ET AL., 2010). The increase in input prices, fertilizers, energy, irrigation water, transportation, population growth, and annual weather variation created variability in crops and price fluctuations (BÄCKMAN & SUMELIUS, 2009; STAGE ET AL., 2010). The rainy season and floods have effect on supply and prices of vegetables, especially in the intra-urban areas where some parts of the land are water-logged.

The country enjoyed abundant potential supply of vegetables, but with high losses and low rate of consumption. ELRASHEED & AWAD, (2009) indicated that production of potato exceed the consumption and led to huge production losses. The rate of vegetable consumption in urban Khartoum still lagged far behind the international recommendation. In Khartoum, with a shortage in internal supply, rural areas contributed a great share in the consumed quantities. This contribution of rural areas signifies one of the main linkages between rural and urban areas.

The relationship between prices and supply was predicted by the traditional cobweb theory where farmers respond to lagged price (ELRASHEED & AWAD, 2009; JOHNSON & PLOTT, 1989; SHONKWILER, 1982). Due to the short crop cycle of leafy vegetables, farmers tend to respond to market prices. So they decide to grow the crop with low supply and high price. When the crop is ready for harvest, its supply increases in the market, the price fells down and the targeted profits cannot be reached. To reduce harvesting costs, farmers prepare their land for the next crop without removing the previous crop (OLSON, 2011).

Supply responded to prices and farmers shift from one product to another to increase their outcomes. Traders are encouraging vegetable supply through the provision of loans to the farmers, which usually targets specific crops. Some traders bring produce from different regions of the country where the possibility to grow crops varies (EMAM, 2011). The price at harvest time is at its lowest level and farmer may lose (ELRASHEED & AWAD, 2009). Farmer sells part of their products at harvest time and store part to sell when the price increases (ELRASHEED & AWAD, 2009). Opportunities to get higher return increases with off-season production. The supply flows from other areas affect prices of different crops differently as the case with the drop in tomato price during July 2009 which confirmed by EMAM (2011).

The consumer nominal and real prices, for almost all tested vegetable prices, showed significant variation with the time variable, year, except for real prices for onion, squash, and tomato. Real prices of onion, squash, and tomato showed significant differences among

months, which indicate the high effect of seasonality on prices. This reflects that changes in nominal and real prices of some vegetable over time reflect on producers gains. The main issue is that, if the real prices of production inputs and means change significantly within time, they will affect farmer's status positively or negatively. On the other hand, the change in consumers' income and urban population rise also have affect on producers' incomes through the change in the demand.

When farmers were asked to compare urban markets during 1990 and nowadays, they indicated that "middlemen" and "street taxes" emerged as a problem not observed previously. The higher demand in the past in comparison to supply had lead to low losses in crops, stable prices, and high return.

The need to improve the market performance will be through improving market infrastructure and supporting policies. The increase of the shelf life of vegetable products and decreased harvest losses (ELRASHEED & AWAD, 2009) will be beneficial in stabilizing prices and that will lead to more return to farmers and traders through more sales. Crop management and technologies such as post harvest treatments; storage conditions, and use of late-maturing varieties will decrease losses and improve the situation (DIAS ET AL., 2003; ELRASHEED & AWAD, 2009).

4.5. Conclusion

The high urban demand for vegetables due to extended urbanization, rapid population growth, and rise in incomes lead to expansion in the cultivation of vegetable crops in the city. Also are encouraging rural producers to bridge the gap and gain more income. Part of the consumed vegetables such as onion, tomato, potato, pumpkins, etc originates from different areas and regions, peri-urban and/or rural sites in the country. Perishable vegetables need to be improved, especially their shelf life, which will increase the stability of prices and decrease losses.

The low vegetable consumption in developing countries can be improved through increment and diversification of production. In addition to that raise, awareness of nutritional value and health concerns of vegetable consumption together with improvement in the income level will also increase the demand and raise vegetable consumption.

Seasonality, availability, supply and demand have a great effect on vegetable prices in the short and long terms. Provision of market information will support farmers in price expectation and decisions regarding crop production. The improvement of market facilities and structures, production credit and support policies will improve the welfare of both food producers and consumers.

Further studies are needed and recommended as researchable agenda related to factors affecting vegetable consumption at household level in urban and peri-urban areas in order to enhance consumption and support production.

4.6. References

ABDELGADIR, K. E. (2002): Survey of city experiences with credit and investment for urban Agriculture interventions: Sudan case, Wadramli Agricultural Cooperative Society. Khartoum city, 2002. Paper prepared for UN HABITAT, UMP-LAC, IPES and IDRC.

AHMED, M. K. and MOHAMED, E. I. (1997): Indigenous vegetables of Sudan: production, utilization and conservation. In: GUARINO, L. (Ed.) (1997): Traditional African vegetables. Proceedings of the IPGRI International Workshop on Genetic Resources of Traditional Vegetables in Africa: Conservation and Use. 29-31 August 1995, ICRAF-HQ, Nairobi, Kenya International Plant Genetic Resource Institute.

AJAIMI, A. A., MAKI, H. M. M., AHMED, M. I., HUSEIN, A. A., ELSHAFIE, B. M., SAAD, M. M. M., ELTAHIR, F. E. and ABDELLATIF, I. A. (2005): Food consumption and nutritional situation in Khartoum state (2002-2003). Ministry of Agriculture and Forestry, unpublished Arabic reports.

BÄCKMAN, S. and SUMELIUS, J. (2009): Identifying the driving forces behind price fluctuations and potential food crisis. Discussion Papers No35, Department of Economics and Management, University of Helsinki. Available at: http://www.mm.helsinki.fi /mmtal/abs/DP35.pdf. Accessed 23 June 2010.

BRYLD, E. (2003): Potentials, problems, and policy implications for urban Agriculture in developing countries. Agricultural and Human Values 20: 79-86.

CASAVANT, K. L., INFANGER, C. L. and BRIDGES, D. E. (1999): Agricultural economics and management. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

CBS (CENTRAL BUREAU STATISTICS) (2010): Fifth population census 2008. Available at: http://www.cbs.gov.sd/ Tiedadat/Tiedadat5th.htm. Accessed 7 July 2010.

CWIK, P. F. (2004): An investigation of inverted yield curves and economic downturns. Ph. D. dissertation, Graduate Faculty, Albama University.

DIAS, T. J. M., MALUF, W. R., FARIA, M. V., FREITAS, J. A. DE, GOMES, L. A. A., RESENDE, J. T. V. and AZEVEDO, S. M. de (2003): *Alcobaça allele* and genotypic backgrounds affect yield and fruit shelf life of tomato hybrids. Scientia Agricola 60(2): 269-275.

DOGONDAJI, S. D., BABA, K. M. and MOHAMMED, I. (2007): Profitability and resource use efficiency in dry season onion production in Sokoto and Kebbi states, Nigeria. International Journal of Agriculture and Rural Development 9: 35-39.

ELRASHEED, M. M. M. and AWAD, F. H. B. (2009): Economics of potato production and marketing in Khartoum State. Journal of Science and Technology 10(2): 80-91.

EMAM, A. A. (2011): Evaluating marketing efficiency of tomato in Khartoum State, Sudan. Journal of Agriculture and Social Sciences 7: 21-24.

FAO (2010): Food consumption. Available at: http://www.fao.org/economic/ess/food-security-statistics/en/. Accessed 6 Jan. 2011.

FONSAH, E. G. (2003): Vegetable wholesale price trend. Available at: http://www.ces.uga.edu/Agriculture/agecon/budgets/printed/vegtrend.pdf. Accessed 27 May 2010.

GREIG, L. (2009): An analysis of the factors influencing farmer's choice of crop, Kibamba Ward, Tanzania. Journal of Agricultural Economics 60(3): 699-715.

JOHNSON, M. D. and PLOTT, C. R. (1989): The effect of two trading institutions on price expectations and the stability of supply-response lag markets. Journal of Economic Psychology 10: 189-216.

KHARTOUM STATE MINISTRY OF AGRICULTURE AND FORESTRY (2006): Agricultural survey. unpublished annual report.

KOKOSKI, M. (2010): Getting real: price deflation of nominal values. Journal of Benefit-Cost Analysis 1(1) Article 7.

KOMAREK, A. M. (2010): Crop diversification decisions: the case of vanilla in Uganda. Quarterly Journal of International Agriculture 49(3): 227-242.

MARIAME, F. and GELMESA, D. (2006): Review of the status of vegetable crops production and marketing in Ethiopia. Uganda Journal of Agricultural Sciences 12(2): 26-30.

MOUGEOT, L. J.A. (1993): Overview - urban food self-reliance: significance and prospects. In: Farming in the city: the rise of urban Agriculture. International Development Research Centre Reports, 21(3). Copyright ©IDRC, Ottawa, Canada. Available at: http://idrinfo.idrc.ca/Archive/ReportsINTRA/pdfs/v21n3e/109070.htm. Accessed 21 June 2010.

OLSON, K. D. (2004): Farm management principles and strategies. Iowa State Press, A Blackwell Publishing Company.

OLSON, K. D. (2011): Economics of farm management in a global setting. John Willey and Sons, Inc.

PEPALL, J. (1993): New challenges for China's urban farmers. In: Farming in the city: the rise of urban Agriculture. International Development Research Centre (IDRC) Reports, 21(3). Copyright ©IDRC, Ottawa, Canada. Available at: http://idrinfo.idrc.ca/Archive/ReportsINTRA/pdfs/v21n3e/109071.htm. Accessed 23 June 2010.

PRAIN, G. (2006): Urban harvest: A CGIAR Global Program on Urban and Peri-urban Agriculture. A paper presented in the workshop titled: Urban/peri-urban Agriculture in the Asian and Pacific region. held in Tagaytay City, Philippines, 22-26 May 2006. Available at: http://www.agnet.org/activities/sw/2006/729863362/ Accessed 11 Oct. 2010.

REGMI, A. and DYCK, J. (2001): Effects of urbanization on global food demand. In: REGMI, A. (Ed.): Changing structure of global food consumption and trade. WRS No. (WRS01-1) 111pp, May 2001. Available at: http://www.ers.usda.gov/ publications/wrs011/wrs011e.pdf. Accessed 15 July 2010.

SALEHI, L., EFTEKHAR, H., MOHAMMAD, K., TAVAFIAN, S. S., JAZAYERY, A., and MONTAZERI, A. (2010): Consumption of fruit and vegetables among elderly people: a cross sectional study from Iran. Nutrition Journal 9(2).

SHONKWILER, J. S. (1982): An empirical comparison of agricultural supply response mechanisms. Applied Economics 14: 183-194.

SPSS Inc. (2004): The statistical Package of Social Science, version 13.

STAGE, J., STAGE, J. and MCGRANAHAN, G. (2010): Is urbanization contributing to higher food prices?. Environment & Urbanization 22(1): 199-215.

THOMPSON, J. L., GEBAUER, J., HAMMER, K., and BUERKERT, A. (2010): The structure of urban and peri-urban gardens in Khartoum, Sudan. Genetic Resources Crop Evolution 57: 487-500.

USAID (2009): Adjusting prices for inflation and creating price indices. FEWS NET Markets Guidance, No 3. Available at: http://www.fews.net/docs/Publications/ MTGuidance_Price Adjustment for Inflation_No3_En.pdf. Accessed 7 May 2010.

WHO (2003): Diet, nutrition and the prevention of chronic diseases. WHO technical report series; 916, Report of a Joint WHO/FAO Expert Consultation Geneva.

Chapter 5. Use of urban agricultural land for red brick production in Khartoum, Sudan*

This chapter is submitted to Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS) as:

Ishtiag Abdalla, Sahar Babiker Abdalla, Kamal El-Siddig Detlev Möller and Andreas Buerkert: Effects of red brick production on land use, owner income, and greenhouse gas emissions in Khartoum, Sudan

Abstract

In many cities of developing countries urbanization and population growth encourage the rapid linkage of different land use patterns such as residential areas, factories, agricultural fields, vegetable gardens and empty open spaces. In Khartoum (Sudan) a particular factor shaping urban land use is the rapid expansion of red brick making (BM) for the construction of houses. This activity takes place on the most fertile agricultural "Gerif" soils along the Blue and River Niles banks. The objectives of this study were to assess the profitability of BM, to explore the income effects among farmers and kiln owners, to measure the dry matter (DM) and nutrient content of nitrogen (N), phosphorus (P), potassium (K) and organic carbon (C_{org}) in cow dung used for BM activities, and to estimate the greenhouse gas (GHG) emission from burned biomass fuel (cow dung and fuel wood). To this end 49 kiln owners were interviewed during July and August 2009 using a semi-structure questionnaire that allowed collecting socioeconomic and variable cost data for a descriptive analysis, budget calculations, and the determination of Gini coefficients. Samples of cow dung were collected directly from the kilns and analyzed for N, P, K and C_{org}. To estimate GHGs emissions the modified approach of the Intergovernmental Panel on Climate Change (IPCC) was used. The land rental value from red brick kilns was estimated at 5-fold the rental value from agriculture; the land rent to total cost ratio was 29% for urban farms compared to 6% for BM. The Gini coefficients indicated that income distribution among kiln owners was more equal than among urban farmers. Our data indicate that annually 856 t DM^{-1} of cow dung and 36 t DM^{-1} of fuel wood are used for BM activities the latter being equivalent to a total of 106 m^3 cut wood. Using IPCC default values GHG emissions from fuel wood and cow dung amounted to 60 and 1,236 t $year^{-1}$, respectively. The results also show the potential of more efficient brick kilns allow to reduce the amount of fuel consumptions and GHG emissions and thus the negative side effects of local brick making on agroecosystems.

Key words: Brick kilns, Biomass fuel, Gini coefficient, GHG emissions, Return to land

5.1. Introduction

Population growth and urbanization enhance the needs of urban residents for food, energy and shelter. These enhance the pressure on land which is reflected in strong increases of agricultural land prices in urban areas (BRYLD, 2003; LANKOSKI & OLLIKAINEN, 2008; LOVELL, 2010; MUTO, 2006; PRAIN, 2006; SAZAK, 2004). The latter often leads to the transfer of agricultural land use from inner city areas to more peripheral locations (SIMATELE & BINNS, 2008; SINGH & SARFARAZ ASGHER, 2005).

A recent remote sensing study provided solid evidence of the large spatial expansion of Khartoum, the capital city of Sudan, over the past 50 years (Schumacher et al., 2009). In this process the ratio of built-up area to urban agricultural area has increased from 2.0 in 1972 to 4.7 in 2009. From 2009 to 1958 this has led to a decrease of agricultural area in the core zone of the city by 60% (SCHUMACHER ET AL., 2009) and also to an increased demand for construction materials such as bricks whereby their making provides an employment opportunity for the urban poor (AUBRY ET AL., 2010). In Khartoum brick making (BM) is mainly practiced on the Blue and River Niles banks, the most fertile lands locally referred to as “Gerif”, where it competes with urban agricultural activities that are traditionally practiced there (AUBRY ET AL., 2010; EL-KAROURI, 1979; JENSEN & PEPPARD, 2004;). To integrate BM into the diverse land use pattern of urban areas remains a challenge to the city municipality and to urban planners (LOVELL, 2010).

Red bricks are the major building material in Sudan’s urban areas (MEPD/HCENR, 2003) and most of them are produced using traditional techniques whereby biomass such as cow dung and wood is used as an energy source. Less than 2% of total red brick is produced using fossil fuel (ALAM & STARR, 2009). Red brick making is known as an important source of urban greenhouse gas (GHGs) emissions given the low combustion efficiency of the fuels used (STREETS & WALDHOFF, 1999). The main components in the BM process are loose and compacted cow dung, clay, water and fuel wood (ALAM & STARR, 2009) whereby clay slurry made from Nile flood sediments is mixed with loose cow dung, pressed into moulds and left to dry in the sun. Subsequently, the raw bricks are burned using compacted cow dung and wood as a source of energy (ALAM, 2006).

During the last decades the overall production of red bricks in Sudan has strongly increased from an estimated 134 Mio in 1975 to 1,804 Mio in 2004 and to 2,800 million in 2006 (ALAM, 2006; HAMID, 2002). In Sudan total Kiln number increased from 1,750 in 1995 to 3,450 in 2005, of which 2000 are located in Khartoum (ALAM & STARR, 2009). Typically BM is a small-scale, labor intensive industry (JENSEN & PEPPARD, 2004) and countrywide the number of workers employed in this sector amounts to about 35,000 of which 50% are employed in Khartoum and 38% in the Central States (ALAM, 2006). Most of the laborers are working on a temporary basis because their payment is based on the quantity produced and not on working hours (JENSEN & PEPPARD, 2004). The health risks related to this activity, particularly exposure

to dust, combustion gases and to heat, makes it difficult to work continuously in a kiln (ALAM, 2006). Also, the annual floods of the River Nile, force most of the kilns to stop operation from July to September.

Practicing of BM on the River Nile banks in the midst of agricultural lands has multiple effects on vegetable and fruit tree production. Due to the heat, soot and smoke particles deposited on the leaves, plant respiration and photosynthesis may be affected (ALAM & STARR, 2009). This has also been reported from Vietnam where kilns are located near rice fields (LE & OANH, 2010; JENSEN & PEPPARD, 2004). Additionally, the soil pit excavation for BM on the River banks make agricultural areas more vulnerable to the erosive floods of the River Nile (AHMED ET AL., 2010) and it may prevent cultivated land to be enriched by sediment deposits (ALAM, 2006). Also, the soil surface will be transformed irreversibly (SINGH & SARFARAZ ASGHER, 2005). Last, the use of substantial amounts of fuel wood accelerates deforestation (MEPD/HCENR, 2003) and leads to the emission of GHGs such as carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), nitrous oxide (N_2O), nitric oxide (NO), and nitrogen oxide (NO_x; ALAM & STARR, 2009).

Following von Thünen's theory of land rent gradient (VON THÜNEN, 1930) the competing use for urban land should lead to a move of agricultural lands from inner city areas to the peri-urban space which has, however, never been verified in Sudan even if the model has been used elsewhere to study the effect of different factors on spatial shifts in land usages, value and price (LANKOSKI & OLLIKAINEN, 2008; MUTO, 2006; SAZAK, 2004).

Valuation of land usage maximizes income for land owners at the expense of land users for whom land is an input factor rather than a resource (SAZAK, 2004). In a recent study XU (2003) used the Lorenz curve and Gini coefficient as indicators of income equality among households, an approach which was also chosen in this study. We wanted to examine the socioeconomic characteristics of red brick kiln owners, the benefit cost ratios (B/C) for agricultural activities and red brick production, the dry matter (DM), nitrogen (N), phosphorus (P), potassium (K) and organic carbon (C_{org}) consumption in cow dung-based BM, the reasons why cow dung is used for BM rather than as an organic fertilizer in urban vegetable production, the cash value of cow dung and mineral fertilizers, and the contribution of brick kilns to GHGs emission.

5.2. Methodology

5.2.1. Site description

The study area comprised the banks of the River Nile and the Blue Nile starting from the confluence of the Blue and White Nile in central Khartoum (15° 40´ N, 32° 30´ E, 382 m a.s.l), located within the semi-desert climate zone of Sudan (HAMAD & EL-BATTAHANI, 2005; MUBARAK ET AL., 2010). There are three climatic seasons (ELAGIB & MANSELL, 2000), the hot dry summer (April to June), the cool dry winter (October to March) and the autumn (July to September) with mean monthly temperatures ranging from 22.1 to 33.7°C. Average annual rainfall ranges from

100-300 mm (HAMAD & EL-BATTAHANI, 2005; MUBARAK ET AL., 2010). High waters of the Nile typically coincide with heavy rainfalls from July to August leading to the occurrence of floods (BARAKAT, 1995; HAMAD & EL-BATTAHANI, 2005). During these events the width of the River Nile increases from an average of 400 m to up to 1000 m (AHMED ET AL., 2010; DAVIES & WALSH, 1997). Flooding of the river banks for almost three months heavily influences the land use system in the affected areas (THOMPSON ET AL., 2010).

5.2.2. Data collection and sampling

For this study a total of 49 red brick kilns were randomly selected and Kiln owners or their agents were interviewed using a semi-structured questionnaire from July-August 2009. Kiln locations were recorded using a hand-held Geographical Positioning System (GPS; Trimble Pathfinder, Sunnyvale, CA, USA; Figure 5.1). The data collected from the respondents included general information such as age, education, land ownership, number of kilns managed or owned and length of time during which the kilns are operated (months per year). Detailed information about the inputs used in BM and prices of inputs and product were recorded for the different seasons.

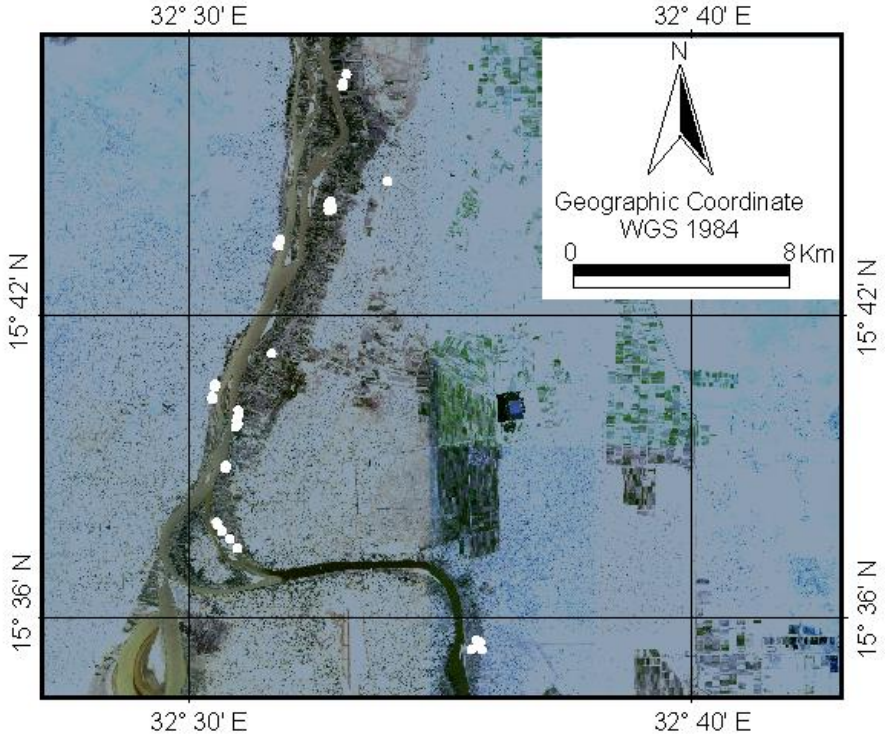

Figure 5.1. Google Earth Pro image (Google, Mountain View, CA, USA) of Khartoum, Sudan, 2009. The white dotes indicates the location of the 49 traditional kilns surveyed on the banks of the Blue Nile and the River Nile.

On the other hand 15 intra-urban farmers and 31 peri-urban animal raisers were interviewed from July-August 2009 and information related to their land's share rental value and annual income for intra-urban farmers and annual returns from dung for the animal raisers was collected.

5.2.3. Data analysis

Descriptive analysis was used to identify the socioeconomic aspects related to the kiln owners. The change ratio (((Price at the end of season – Price at the beginning of season) / Price at the beginning of season) * 100) was calculated for all inputs and outputs. The cost value of inputs (mainly for land rent, loose dung, compacted dung, fuel wood, and labor), and other costs such as taxes and fees was calculated. Subsequently, the cost of production per 1000 bricks, the profitability of the activity (Total return – Total cost), and the Benefit cost ratio ((B/C) = (Total revenue / Total cost)) was computed. The Average Product (AP), which indicates the average productivity of each unit of variable input being used (CASAVANT ET AL., 1999), for inputs and the average cost of inputs as loose dung, labor, biomass fuel, and other costs were also calculated.

To determine the financial impact of red brick and agricultural production for both intra-urban farmers and kilns owners, the Gini coefficient (G), a measure of income inequality, was used. The Gini coefficient ranges between 0 and 1, whereby 0 indicates perfect equality (everyone has the same income) and 1 corresponds to perfect inequality (one person has all available income, and everyone else has no income). This coefficient is derived from the Lorenz curve which describes the relationship between the cumulative percentage of the population and the income (SHIDEED & EL MOURID, 2005). For the sake of this study the more practical Brown formula of the Gini coefficient was applied (BROWN, 1994; XU, 2003) whereby the net cash return (total cash receipt minus total cash payment) was used as data input:

$$G = \left| 1 - \sum_{k=0}^{k=n-1} (X_{k+1} - X_k)(Y_{k+1} + Y_k) \right|$$

Where:

G= Gini coefficient

X_k= cumulated proportion of the population variable, for k = 0, …, n, with X_0 =0, X_n =1

Y_k= cumulated proportion of the income variable, for k = 0, …, n, with Y_0 =0, Y_n =1

k = case number

n = number of cases

The Benefit cost ratio was calculated as: total revenue / total cost (PHILLIPS & PHILLIPS, 2005) to obtain the return per monetary unit spent on each activity.

5.2.4. Nutrient losses from cow dung and GHGs emissions

To estimate losses of N, P, K and C_{org} in DM basis and GHGs emission (CO_2, CO, CH_4, N_2O, NO, and NO_x) from cow dung, loose and compacted dung samples were collected from different kilns and analyzed for their N, P, K and C_{org} using standard laboratory procedures. In order to estimate the quantity of dung used annually and to produce 1000 bricks, loose and compacted dung density were measured (weight per volume). As respondents were questioned about the number of lorries used for brick production, the capacity of one lorry (DM weight

contained in one dung-filled lorry) was estimated and used to calculate the consumption of N, P, K, C_{org} in BM.

Prior to analysis loose and compacted cow dung samples were dried to constant weight at 65°C and total N and C_{org} measured using a Vario MAX CN/CHN/CNS analyzer (Elementar Analysensysteme GmbH, Hanau, Germany). To estimate P and K concentrations samples were oven dried at 105°C for DM determination, burned at 550°C and the resulting ash dissolved in HCl. The P concentration was measured colorimetrically (Hitachi U-2000 spectrophotometer, Hitachi Ltd., Tokyo, Japan) according to the vanado-molybdate method (GERICKE & KURMIES, 1952) and K was determined by flame photometry (Auto Cal 743, Diamond Diagnostics, Holliston, MA, USA).

Nitrogen and C gaseous losses from loose and compacted dung and from fuel wood were estimated using modified procedures from the Intergovernmental Panel on Climate Change (IPCC, 1996) as follows:

$TC_r = TB_b \times FB_{ox} \times B_c$

Where TC_r = total carbon released (t C), TB_b = total biomass burnt (t DM), FB_{ox} = fraction of biomass oxidized, and B_c = biomass carbon content (t C t DM^{-1}). A default value of 0.9 was used for the fraction of biomass oxidized for both types of biomass material (dung and wood). Under the assumption of complete combustion, a C concentration of 45% was used for dung biomass C that is 0.45 t C t DM^{-1}.

Non-(CO_2) gaseous emissions (CO-C, CH_4-C, N_2O-N, NO-N, and NO_x-N) were calculated from the TC_r as follow:

$CO\text{-}C = TC_r \times ER$

$CH_4\text{-}C = TC_r \times ER$

$N_2O\text{-}N = TC_r \times ER \times N/C$

$NO\text{-}N = TC_r \times ER \times N/C$

$NO_x\text{-}N = TC_r \times ER \times N/C$

Where the specific emission ratios (ER) for the Non-CO_2 gaseous were CO = 0.060, CH_4 = 0.012, N_2O = 0.007, NO = 0.121 and NO_X = 0.121 and N/C ratio in biomass = 0.01. CO_2-C emission was derived from CO-C, CH_4-C gaseous emission and TC_r by:

$CO_2\text{-}C = TC_r - (CO\text{-}C + CH_4\text{-}C)$

Emissions were calculated separately for loose and compacted dung; once using the IPCC default values for FB_{ox}, B_c and N/C ratio and once using our own data obtained from the laboratory analysis for the FB_{ox} ((Oven dry weight - Ash weight) / Oven dry weight)), B_c (t C t DM^{-1}) and the N/C ratio for loose and compacted dung. Emissions from the fuel wood burning were similarly calculated using only the IPCC default values (FB_{ox} = 0.9; B_c = 0.5 t C t DM^{-1}).

To estimate the removal from biomass wood used as fuel, a default density value of 0.65 t DM m^{-3} (DIXON ET AL., 1991) was used to convert wood biomass of deciduous trees (t DM) into

cubic meter (m^3); for branches and small trees an expansion ratio of 1.90 was added (BROWN ET AL., 1989):

Total deforested wood (m^3) = Deciduous trees (m^3) * 1.90.

5.3. Results

In 2009 about 76% of the urban agricultural land was under share cropping whereby the land rent ranged from 25-33% of cropping returns after deducting the variable costs such as seeds, fertilizer, and pesticides. Animal raisers preferred selling their dung to red brick producers rather than to farmers, on fixed periods, weekly or monthly, depending on herd size. The annual average return from manure was about 4,528.2 SDG (one Sudanese Pound = 0.4 US$) for average herd size of about 27.4 Tropical Livestock Unit (TLU; ILCA 1990).

5.3.1. Socioeconomic characteristics

Red brick kiln owners were on average 45 years old having from 2 to 15 family members, 77% were educated (at least primary schooling), the majority had no other income than BM, and more than tenth of the respondents had more than one kiln. Most of them depended on rented land whereas farmers preferred share cropping because of the high rent value. Red brick production in the traditional kilns lasts 6-12 months annually with an average of 10 months. Only sixth of the respondents were land owners, while most of them were renting their land (Table 5.1). The average rent value paid by kiln owners by far exceeded the average value received from farmers as return from agricultural land use.

Table 5.1. Socioeconomic characteristics of the interviewed brick kilns owners (n = 49) in Khartoum, Sudan, 2009. Data show means followed by their standard deviation.

Parameter	Mean
Age (years)	44.7 (9.3)
Family size (members)	7.3 (2.4)
No of working months	9.8 (1.2)
Educated (%)	77
Main activity (%)	
Brick making	86
Other	14
Land ownership (%)	
Own land	16.0
Rented land	79.5
Both (own & rented)	4.5
Kiln number (%)	
One brick kiln	86
More than one kiln	14

Source: Formal survey 2009.

5.3.2. Production inputs, cost and benefits

Clay, cow dung, wood, and labor are the main inputs used in the BM process. Input and output prices changed across seasons whereby the rainy season, from late July to end September, is called “off-season” and the dry season, from October to July, is the “production-season”.

The loose dung average price ranged from 43-66 SDG t^{-1} DM^{-1} while the compacted dung average price ranged from 12-29 SDG t^{-1} DM^{-1} (Table 5.2, Figure 5.2). Most of the interviewed kiln owners indicated that during the off-season, the price of loose dung was lowest and started to increase only at the beginning of the production season, due to the higher competition for this resource. The wood price in comparison was relatively stable during the season. 73% of the respondents use only wood as an energy source in BM while the remainder uses both wood and compacted dung.

Table 5.2. Prices (in SDG[1] t^{-1} dry matter (DM)) of loose dung, compacted dung and wood among sampled from kiln owners (n = 49) in Khartoum, Sudan, 2009. Data show means followed by their standard deviation.

Parameter	% of kiln	Mean	Change ratio (%)*
Loose dung			
Beginning of season	96	42.6 (5.7)	
Middle of season	92	55.1 (7.3)	
End of season	100	70.3 (7.2)	65.0
Average prices	100	55.1 (4.6)	
Compacted dung			
Beginning of season	85	15.8 (2.6)	
Middle of season	92	23.7 (4.1)	
End of season	92	25.5 (5.9)	61.4
Average prices	100	22.1 (4.1)	
Wood	100	343.8 (21.3)	

[1] SDG (New Sudanese Pound) ≈ 0.4 US$
*Change ratio (%) = (((price at the end of season – price at the beginning of season) / price at the beginning of season) * 100)
Source: Formal survey 2009

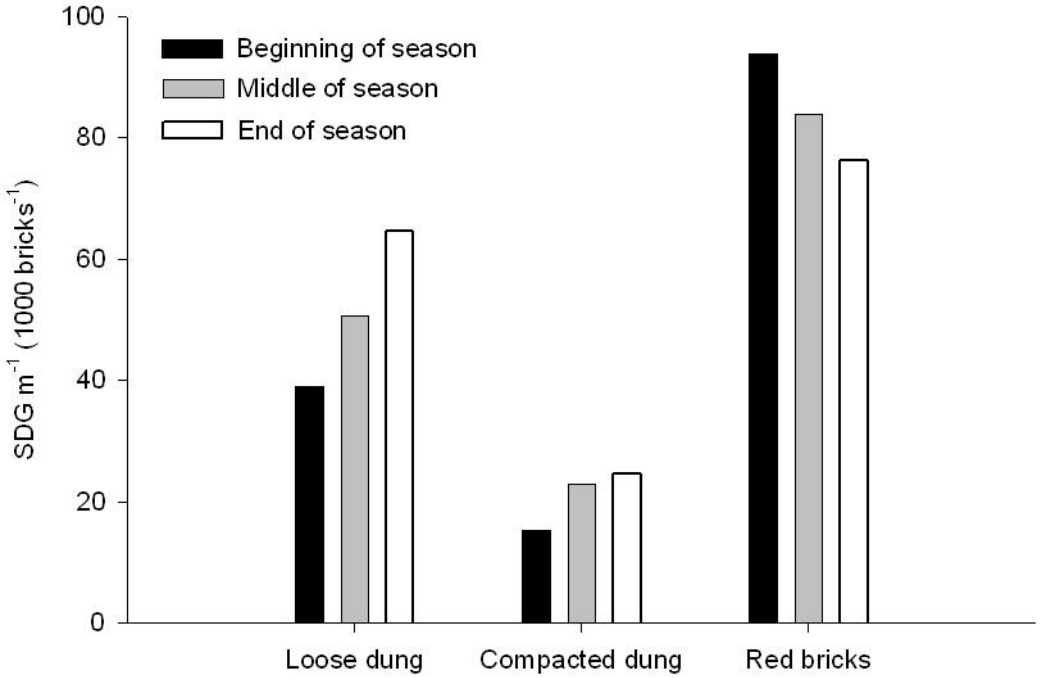

Figure 5.2. Prices (SDG t^{-1}) of loose and compacted dung and red brick (1000 bricks) during the working months of sampled kilns (n = 49) in Khartoum, Sudan, 2009. All data are in New Sudanese Pounds, 1 SDG, ≈ 0.4 US$.

The change ratio of the inputs prices was higher than that of the output prices. At the onset of the season the prices of loose and compacted dung were low and the brick price was high. Thereafter dung prices increased and brick prices declined as a consequence of raising production (Figure 5.2).

The Average Product (AP) of red bricks varied with input quality whereby the AP of loose dung ranged from 2,950-4,660 bricks t^{-1} DM^{-1} and compacted dung burning yielded range between 2,490-4,980 bricks t^{-1} DM^{-1}. For wood AP ranged from 25,710-180,000 bricks t^{-1} (Table 5.3). Cost benefit calculations showed that 57% of total expenses were labor costs while loose dung costs were 22%, fuel wood costs 13% and land rent 6%. The B/C ratio for red BM was 1.25 SDG for every SDG invested (Table 5.4).

Table 5.3. Average Product (AP) in 1000 bricks t^{-1} of loose and compacted dung and 1000 bricks t^{-1} of wood among sampled kiln owners (n = 49) in Khartoum, Sudan, 2009. Data show means followed by their standard deviation.

Parameter	% of kiln owners	Mean
Loose dung AP	86	3.706 (0.4235)
Compacted dung AP	27	4.056 (0.7728)
Wood AP	100	45.345 (99.5687)

Source: Formal survey 2009.

Table 5.4. Average cost, average return, and benefit cost ratio (B/C) in SDG[1] 1000 $bricks^{-1}$ for sampled farmers (n = 44) in Khartoum, Sudan, 2009.

Parameter	Mean
Rent cost	4.0
Total labor cost	39.0
Cost of loose dung	15.0
Burning cost	9.0
Other Cost	1.5
Average revenue	85.2
Average cost	68.0
Net revenue	17.2
B/C	1.25

[1] SDG (New Sudanese Pound) ≈ 0.4 US$.
Source: Formal survey 2009.

5.3.3. Income distribution among farmers and red brick kiln owners

Household incomes differed greatly, reflecting differences in family activities. Farmers and kiln owners generated different incomes from "Gerif" land leading to per capita incomes that averaged 2.4 SDG day^{-1} for farmers and 13 SDG day^{-1} for kiln owners. With a Gini coefficient of about 0.38 the income of red brick kiln owners was more equally distributed than of the farmers (Table 5.5). However, despite the higher return the B/C ratio of BM was lower than that of urban farming activities.

The share of land rent in total costs varied greatly among farm and BM households, nearly up to five folds.

Table 5.5. Average net return, total return and total cost for farms and kilns (in SDG[1]), Gini-coefficient, benefit cost ratio (B/C), and land share of total cost for farms and kilns in urban Khartoum, Sudan, 2009.

Items	Red brick kiln owners (n = 44)	Urban farmers (n = 15)
Average total return	147,229.60	8,267.00
Average total cost	116,355.30	3,718.20
Average net return	30,874.3	4,626.00
Gini coefficient	0.38	0.49
B/C	1.27	2.22
Land share of total cost (%)	6.00	29.00

[1] SDG (New Sudanese Pound) ≈ 0.4 US$
Source: Formal survey 2009

5.3.4. Biomass consumption and GHGs emission

At the time of the study the price of one bag (50 kg) of urea (46% N) and TSP (triplesuperphosphate, 20% P) was 65 SDG, while prices of the equivalent amounts of N were 70 and 27 SDG from loose and compacted dung and were 107 and 29 SDG of P from loose and compacted dung, respectively. Alternatively, the price for 1 bag (50 kg) of NPK (18:18:5) was 150 SDG while the equivalent amounts of nutrients from dung was 31 SDG for loose dung and 8 SDG for compacted dung.

Average amount of C_{org} varied from 354 ± 4.2 to 276 ± 29.1 g kg^{-1} DM, in loose and compacted dung, respectively while the K concentration in compacted dung (33 ± 2.0 g kg^{-1} DM) was 153% higher than in loose dung (13 ± 2.0 g kg^{-1} DM). For N and P concentrations slight difference were found between loose and compacted dung (Figure 5.3).

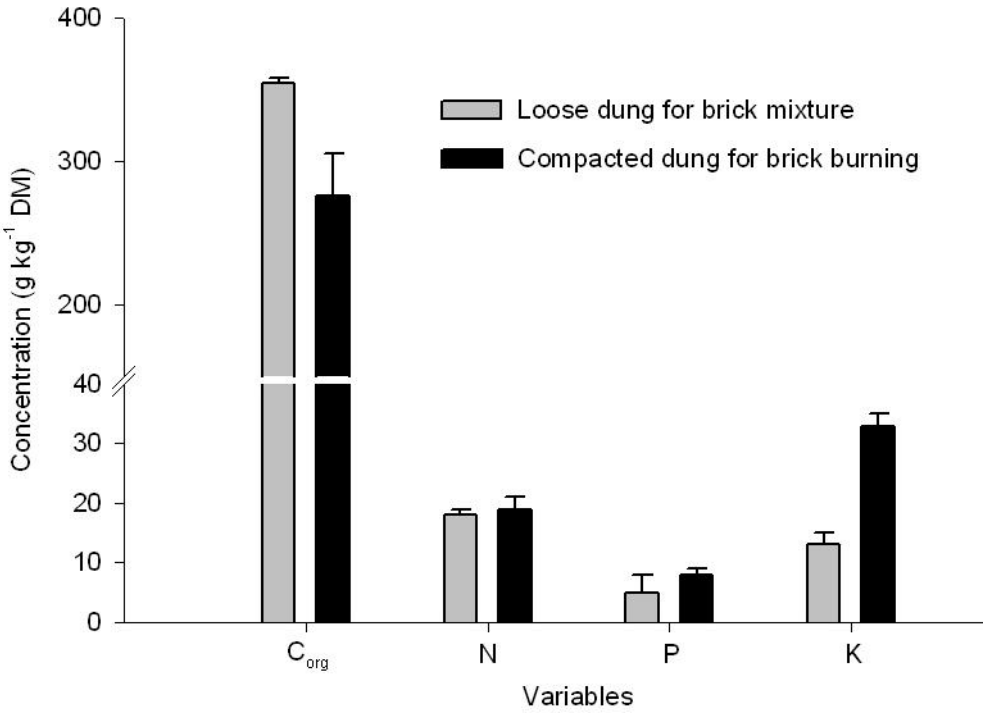

Figure 5.3. Average concentrations of organic carbon (C_{org}, n = 5), nitrogen (N, n = 5), phosphorus (P, n = 10) and potassium (K, n = 10) in loose and compacted dung used in red brick kilns of Khartoum, Sudan, 2009.

The capacity of one dung-filled lorry used in BM production is estimated to be about 6.5 t DM and 24 t DM of loose and compacted dung, respectively, with a density of 0.31 g cm^{-3} and 1.14 g cm^{-3}. The annual DM consumption of loose dung exceeded that of compacted dung by almost 20% yielding on average 1,677,000 bricks (Table 5.6). Overall wood consumption for BM was much lower than dung consumption, but still the consumption of fuel wood from the annual wood harvested was equivalent to 53% of the round wood and the rest was branch wood (Table 5.6).

Table 5.6. Average amounts of dry matter (DM), organic carbon (C_{org}, n = 5), nitrogen (N, n = 5), phosphorus (P, n = 10), potassium (K, n = 10) contained in cow dung and amount of fuel wood used in red brick kilns (n = 49) in Khartoum, Sudan, 2009.

Variables	Consumption of loose dung		Consumption of compacted dung	
	kg 1000 brick^{-1}	t year^{-1} of brick production	kg 1000 brick^{-1}	t year^{-1} of brick production
DM	270	475	247	381
C_{org}	95.6 (1.14)	168.1 (2.01)	68.1 (7.18)	105.3 (11.10)
N	4.9 (0.25)	8.6 (0.45)	4.6 (0.47)	7.1 (0.72)
P	1.4 (0.08)	2.4 (0.14)	1.9 (0.23)	2.9 (0.35)
K	3.5 (0.55)	6.21 (0.97)	8.2 (0.41)	12.6 (0.64)

Production of bricks	Wood consumption (t DM)	Round wood (m^3)	Total harvested wood (m^3)
1000 brick	0.02 (0.001)	0.03 (0.002)	0.06 (0.004)
Bricks year^{-1}	36 (3.5)	56 (5.4)	106 (10.2)

Average brick production year^{-1} = 1,677 x (10^3).

The comparison of our estimates of GHGs emission in kiln-based BM from loose and compacted dung based on the IPPC approach versus actual values obtained from the laboratory analysis for the dung samples yielded surprisingly different results (Table 5.7). According to the analysis, average C concentration of the dung was about 35 ± 0.4% for loose dung and 28 ± 2.9% for compacted dung. Average N/C ratio was about 0.05 ± 0.002 and 0.07 ± 0.003 for loose and compacted dung, respectively, and the fraction of biomass oxidized was 0.68 ± 0.016 and 0.55 ± 0.057, respectively. Consequently, the TC_r, CO_2-C, CO-C and CH_4-C emission of cow dung (loose and compacted) estimated from the IPCC default values exceeded the values derived from measured data by about 50%. The opposite was true for NO_x-N, NO-N and N_2O-N where the calculated values were 3-fold the IPCC values. Apparently, GHGs emission from biomass dung was dominated by CO_2-C and CO-C followed by CH_4-C. As a consequence of the low consumption of wood in BM, emissions from fuel wood were much lower than emissions from dung (Table 5.7).

Table 5.7. Total carbon released (TC_r) and greenhouse gases (GHGs) emission from loose and compacted dung and fuel wood consumed in red brick kilns in Khartoum, Sudan, 2009.

Biomass consumption	GHG emission						
	TC_r	CO_2-C	CO-C	CH_4-C	NO_x-N	NO-N	N_2O-N
Loose dung			**Using IPCC default value**				
kg 1000 brick^{-1}	109	101	6.6	1.3	0.1	0.1	0.01
t year^{-1}	192	178	11.5	2.3	0.2	0.2	0.01
			Using own data value				
kg 1000 brick^{-1}	65	60	3.9	0.8	0.4	0.4	0.02
t year^{-1}	115	106	6.9	1.4	0.7	0.7	0.04
Compacted dung			**Using IPCC default value**				
kg 1000 brick^{-1}	100	93	6.0	1.2	0.1	0.1	0.01
t year^{-1}	154	143	9.3	1.9	0.2	0.2	0.01
			Using own data value				
kg 1000 brick^{-1}	37	34	2.2	0.4	0.3	0.3	0.02
t year^{-1}	58	54	3.5	0.7	0.5	0.5	0.03
Fuel wood			**Using IPCC default value**				
kg 1000 brick^{-1}	10	9	0.60	0.12	0.012	0.012	0.001
t year^{-1}	16	15	1.0	0.20	0.020	0.020	0.001

5.4. Discussion

Given the scarcity of "Gerif" soils and alternative land use options, land owners in Khartoum have the choice of renting their land out either for share cropping or BM. Such competition and interaction between agriculture and brick kilns has been reported previously from Vietnam (JENSEN & PEPPARD, 2004), Pakistan (ISHAQ ET AL., 2008) and Sudan (ALAM & STARR, 2009). It leads to a frequent modification of the spatial land use pattern following changes in opportunity costs for land and labour (LANKOSKI & OLLIKAINEN, 2008; MUTO, 2006; SAZAK, 2004; SCHUMACHER ET AL., 2009; SINGH & SARFARAZ ASGHER, 2005). The seasonality of rainfall and of the height of the River Nile waters leads to additional temporal variation of land use (JENSEN & PEPPARD, 2004; THOMPSON ET AL., 2010). Our survey indicated that red BM is more profitable at the beginning of the season rather than at mid-season when most kilns are fully operating. During the former period input prices, mainly dung, are low because of low demand while brick prices are high due to the proximity of the inactive kiln season. Limited opportunity costs for cow dung in agriculture that benefits from the fertilizing floods of the River Nile make the BM activity of great interest to animal producers through the provision of extra income (OMER & FADALLA,

2003). The B/C ratio is higher in crop production than in red BM, but limited land area and higher cost of inputs used are constraints to agricultural production.

Red BM provides employment opportunities and, as indicated by the low Gini coefficient, secures a more even distribution of income among kiln owners (SINGH & SARFARAZ ASGHER, 2005). This leads to the continuous expansion of this industry at the expense of agricultural activities along the Blue Nile and the River Nile regardless of the associated environmental problems for the surrounding populated and crop growing areas (MUTO, 2006; JENSEN & PEPPARD, 2004; SAZAK, 2004).

Currently cow dung in Khartoum state is only used as a fuel for BM activity rather than for agriculture where mineral fertilizers are applied if farmers consider it necessary (ALAM & STARR, 2009; OMER & FADALLA, 2003). Our data indicated that per unit N and P applied cow dung is slightly cheaper than mineral fertilizers. Even though, farmers prefer to apply urea or compound mineral fertilizers because of the faster availability of N compared to manure that at a C/N ratio of 15-20 may lead to temporary N immobilization (WICHERN ET AL., 2004).

Sudan's national GHGs inventory of 1995 (MEPD/HCENR, 2003) reports total emissions of about 25,752,000 t consisting of CO_2 (20,077,000 t), CO (3,280,000 t), CH_4 (1,985,000 t) and other gases such as NMVOC, NO_x, N_2O, HFCs and SO_2 in 1995 of which 78% was emitted as CO_2. In our present study gaseous emissions estimated using the IPCC (1996) approach were equivalent to 1,179 t CO_2 year^{-1}, 49 t CO year^{-1}, 5.5 t CH_4 year^{-1}, 1.4 t NO_x year^{-1}, 0.9 t NO year^{-1} and 0.04 t N_2O year^{-1} from cow dung and 58 t CO_2 year^{-1}, 2 t CO year^{-1}, 0.26 t CH_4 year^{-1}, 0.06 t NO_x year^{-1}, 0.04 t NO year^{-1} and 0.002 t N_2O year^{-1} from woody biomass. Our data indicate that to this total emissions from kiln-based manure burning contribute 10% and from wood burning kilns 0.5%. This reflects the rapid urbanization rate and the related demand for constructions materials (TAHIR ET AL., 2010).

According to the IPCC (1996) the aboveground biomass of tropical forests in African dry zones (rainfall < 1000 mm year^{-1}) ranges from 20 to 55 t DM ha^{-1}. As the average rainfall in dry zone of Sudan ranges from 100 to 300 mm year^{-1} (HAMAD & EL-BATTAHANI, 2005; MUBARAK ET AL., 2010) we assume the aboveground biomass of local forests are at the lower range (20 t DM ha^{-1}). Based on this a wood consumption of 36 t DM year^{-1} would translate to about 2 ha year^{-1} deforested area.

5.5. Conclusions and recommendations

Kiln-based BM on the fertile flood land along the Nile and its tributaries has profound effects on the spatial and temporal land use pattern in Khartoum and offers significant income opportunities for a significant number of kiln owners and their employees. Although the manure and wood-based production of red bricks contributes substantially to the income of kiln owners, improvements in energy efficiency may allow kilns to reduce GHGs emission per unit brick and negative health effects to kiln employees while increasing the overall profitability of this land use

system. There also may be a need to raise farmers' awareness about the benefits of cow dung to maintain C_{org} levels in intensively cultivated "Gerif" soils in Khartoum.

5.6. References

AHMED, A. A., IBRAHIM, S. A. S., OGEMBO, O., BABIKIR, I. A. A. and FADUL, H. M. (2010): Nile River bank erosion and protection. The Nile Basin Capacity Building Network (NBCBN)-RE.

ALAM, S. A. (2006): Use of biomass fuels in the brick-making industries of Sudan: implications for deforestation and greenhouse gas emission. Thesis submitted for an M. Sc. Degree in Forest Ecology, Tropical Silviculture, Department of Forest Ecology, Viikki Tropical Resources Institute (VITRI), University of Helsinki.

ALAM, S. A. and STARR, M. (2009): Deforestation and greenhouse gas emissions associated with fuelwood consumption of the brick making industry in Sudan. Science of the Total Environment 407: 847–852.

AUBRY, C., BA, A., DABAT, M. H. and RAMAMONJISOA, J. (2010): Urban agriculture and sustainable urban landscape. An applied research on two case studies (Madagascar and Senegal). 9th European IFSA Symposium, 4-7 July 2010, Vienna (Austria).

BARAKAT, H. N. (1995): Middle Holocene vegetation and human impact in central Sudan: charcoal from the neolithic site at Kadero. Vegetation History and Archaeobotany 4: 101–108.

BROWN, M. C. (1994): Using Gini-style indices to evaluate the spatial patterns of health practitioners: theoretical considerations and an application based on Alberta data. Social Science and Medicine 38(9): 1243-256.

BROWN, S., GILLESPIE, A. J. R. and LUGO, A. E. (1989): Biomass estimation methods for tropical forests with applications to forest inventory data. Forest Science 35: 881-902.

BROWN, S., SCHREIER, H., SHAH, P. B. and LAVKULICH, L. M. (1999): Modelling of soil nutrient budgets: an assessment of agricultural sustainability in Nepal. Soil Use and Management 15: 101–108.

BRYLD, E. (2003): Potentials, problems, and policy implications for urban agriculture in developing countries. Agricultural and Human Values 20: 79-86.

CASAVANT, K. L., INFANGER, C. L and BRIDGES, D. E. (1999): Agricultural economics and management. Prentice-Hall, Inc. Upper Saddle River, New Jersey 411p.

DAVIES, H. R. J. and WALSH, R. P. D. (1997): Historical changes in the flood hazard at Khartoum, Sudan: lessons and warnings for the future. Singapore Journal of Tropical Geography 18(2): 123–40.

DIXON, R. K., SCHROEDER, P. E. and WINJUM, J. K. (1991): Assessment of promising forest management practices and technologies for enhancing the conservation and sequestration of atmospheric Carbon and their costs at the site level. US Environmental Protection Agency, Office of Research and Development, Washington D.C., US.EPA/600/3-9/067 In: ALAM, S. A. and STARR, M. (2009): Deforestation and greenhouse gas emissions associated

with fuelwood consumption of the brick making industry in Sudan. Science of the Total Environmental 407: 847-852.

ELAGIB, N. A. and MANSELL, M. G. (2000): Recent trends and anomalies in mean seasonal and annual temperatures over Sudan. Journal of Arid Environments 45: 263–288.

EL-KAROURI, M. O. H. (1979): Effect of soil salinity on the productivity of arid lands, with special reference to the Sudan. In: MABBUTT, J. A. (Ed.): Proceedings of the Khartoum workshop on arid lands management. The United Nations University.

GERICKE, S. and KURMIES, B. (1952): Die kolorimetrische Phosphorsäurebestimmung mit Ammonium-Vandadat-Molybdat und ihre Anwendung in der Pflanzenanalyse. Z. Düngg.Pflanzenernähr. Bodenk 59: 235–247.

HAMAD, O. E. and EL-BATTAHANI, A. (2005): Sudan and the Nile Basin. Aquatic Sciences 67: 28–41.

HAMID, M. H. (2002): Industry of red bricks in Sudan: general overview. Building and Road Research Institute (BRRI), University of Khartoum, Sudan, unpublished reports in Arabic.

ILCA (INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA) (1990): Livestock systems research manual. Working Paper 1, vol. 1, (ILCA, Addis Ababa, Ethiopia) available in http://www.fao.org/wairdocs/ilri/x5469e/x5469e08.htm#inter species composition of the livestock holding. Accessed 11 April 2011.

IPCC (1996): Revised IPCC guidelines for national greenhouse gas inventories. vols. I, II and III. Intergovernmental Panel on Climate Change, United Nations Environment Program, World Meteorological Organization, Organization for Economic Co-operation and Development and International Energy Agency.

ISHAQ, M., KHAN, M. A., JAN, F. A. and AHMAD, I. (2010): Heavy metals in brick kiln located area using atomic absorption spectrophotometer: a case study from the city of Peshawar, Pakistan. Environmental Monitoring and Assessment 166: 409–420.

JENSEN, R. and PEPPARD, D. M., JR. (2004): The traditional brickmaking industry and the rural economy of Vietnam. Journal of Asian and African Studies 39(3): 193–207.

LANKOSKI, J. and OLLIKAINEN, M. (2008): Bioenergy crop production and climate policies: a von Thünen model and the case of reed canary grass in Finland. European Review of Agricultural Economics 35(4): 519-546.

LE, H. A. and OANH, N. T. K. (2010): Integrated assessment of brick kiln emission impacts on air quality. Environmental Monitoring and Assessment 171: 381–394.

LOVELL, S. T. (2010): Multifunctional urban agriculture for sustainable land use planning in the United States. Sustainability 2: 2499–2522.

MEPD (MINISTRY OF ENVIRONMENT and PHYSICAL DEVELOPMENT) and HCENR (HIGHER COUNCIL FOR ENVIRONMENT AND NATURAL RESOURCES) (2003): Sudan's first national communications under the United Nations Framework Convention on Climate Change. vol. I: Main

communications. 111p Available at: http://unfccc.int/resource/ docs/natc/sudnc1.pdf. Accessed 30 August 2010.

MUBARAK, A. R., ELSHAMI, O. M. E. and ADAM, A. E. (2010): Short-term effects of tillage on N mineralization from farm yard manure in semi-arid tropical vertisol research. Journal of Agriculture and Biological Sciences 6(2): 157–160.

MUTO, S. (2006): Estimation of the bid rent function with the usage decision model. Journal of Urban Economics 60: 33-49.

OMER, A. M. and FADALLA, Y. (2003): Biogas energy technology in Sudan. Renewable Energy 28: 499–507.

PHILLIPS, P. P. and PHILLIPS, J. J. (2005): Return on investment (ROI) basics (ASTD training basics). Alexandria, Va.: ASTD Press.

PRAIN, G. (2006): Urban harvest: a CGIAR global program on urban and peri-urban agriculture. Paper presented in the workshop titled Urban/peri-urban Agriculture in the Asian and Pacific region. Tagaytay City, Philippines, 22-26 May 2006. Available at: http://www.agnet.org/activities/sw/ 2006/729863362/. Accessed 11 October 2010.

SAZAK, S. (2004): The role of landowners in the transformation of land affected by the metropolitan city, “Corlu”. Land Use Policy 21: 21-31.

SCHUMACHER, J., LUEDELING, E., GEBAUER, J., SAIED, A., EL-SIDDIG, K. and BUERKERT, A. (2009): Spatial expansion and water requirements of urban agriculture in Khartoum, Sudan. Journal of Arid Environments 73: 399–406.

SHIDEED, K., H. and EL MOURID, M. (Eds.) (2005): Adoption and impact assessment of improved technologies in crop and livestock production systems in WANA Region. International Center for Agricultural Research in the Dry Areas (ICARDA).

SIMATELE, D. M. and BINNS, T. (2008): Motivation and marginalization in Africa urban agriculture: the case of Lusaka, Zambia. Urban Forum 19: 1-21.

SINGH, A. L. and SARFARAZ ASGHER, M. (2005): Impact of brick kilns on land use/landcover changes around Aligarh city, India. Habitat International 29: 591–602.

STREETS, D. G. and WALDHOFF, S. T. (1999): Greenhosue-gas emissions from biofuel combustion in Asia. Energy 24: 841-855.

TAHIR, S. N. A., RAFIQUE, M. and ALAAMER, A. S. (2010): Biomass fuel burning and its implications: deforestation and greenhouse gases emissions in Pakistan. Environmental Pollution 158: 2490-2495.

THOMPSON, J. L., GEBAUER, J. and BUERKERT, A. (2010): Fences in urban and peri-urban gardens of Khartoum, Sudan. Forests, Trees and Livelihoods 19: 379–391.

VON THÜNEN, J. H. (1930): Der isolierte Staat in Beziehung auf Landwirtschaft und Nationalökonomie. third ed. Fischer, Jena, Germany, 678p.

WICHERN, F., MÜLLER, T., JOERGENSEN, R. G. and BUERKERT, A. (2004): Effects of manure quality and application forms on soil C and N turnover of a subtropical oasis soil under laboratory conditions. Biological Fertility Soils 39: 165–171.

XU, K. (2003): How has the literature on Gini's index evolved in the past 80 years?. Dalhousie University, Economics Working Paper, Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=423200. Accessed 29 October 2010.

Appendices

Appendix 5.1.

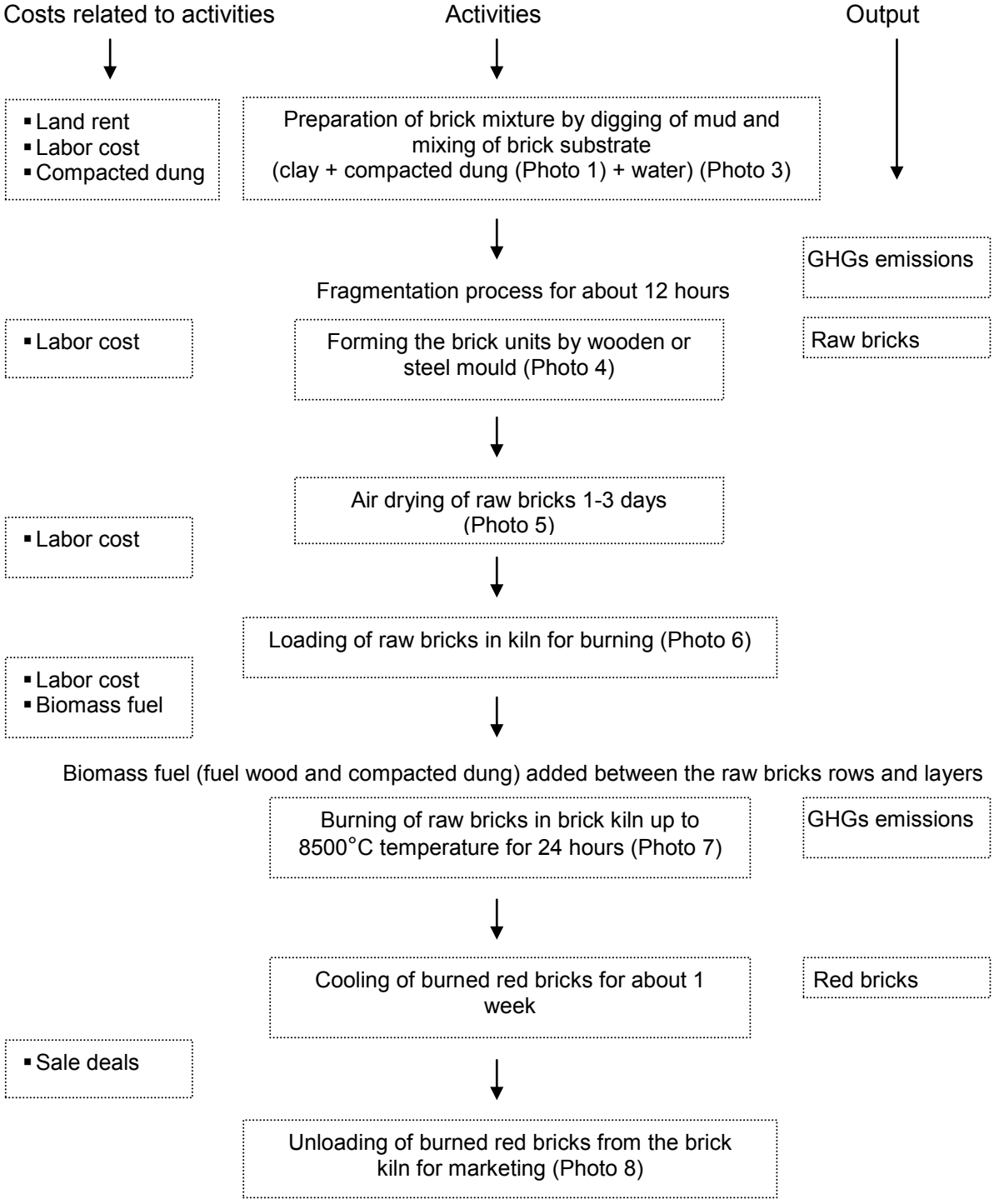

Figure 5.4. Flow chart illustrating the traditional process of production of red bricks in Khartoum, Sudan (modified after Alam, 2006)**.** Photo gallery is given in the appendix 2.

Appendix 5.2. Photo gallary

1. Loose dung used in bricks mixture

2. Compacted dung used for bricks burning

3. Excavation in soil pit for mixing clay and dung

4. Preparation of bricks mixture (clay + loose dung) with water

5. Forming of the mixture to bricks units using steel or wooden mould

6. Air drying of raw bricks units

7. Loading of dried raw bricks in layers for burning

8. Burning of raw bricks in kiln using biomass fuel (fuel wood and compacted dung)

9. Red brick ready for marketing after it has been cooled for about one week

10. Soil degradation due to removal of clay from the River Nile banks for brick mixture

11. Water erosion of soil along the River Nile banks

12. Adjacent locations of brick making kilns and crop cultivation farms

Chapter 6. General discussion and conclusions

6.1. Study area and data collection

The importance of urban and peri-urban agriculture (UPA) in Khartoum is increasing due to population growth and movement from rural to urban areas. With a population of about 5.4 million (CBS, 2009) and growing agricultural areas with an average of 172 ha per year since 1958 (SCHUMACHER ET AL., 2009) the need of food production is increasing. Agricultural activities are sustained by the unique location at the confluence of two big rivers: the Blue and White Niles. The importance of UPA in Khartoum raises the need to investigate into its main features. The characterization and definition of UA demands investigation of different aspects in the study area. Socioeconomic factors are part of the aspects and components that affect UPA. To capture those elements different stakeholders were interviewed formally and informally to collect data and information in the study area during 2007 to 2009. Farmers, mainly crop growers and dairy producers, and Kiln owners or agents were interviewed using semi-structured questionnaires. Also wholesale traders in Shambat central markets were interviewed informally and vegetable prices were collected on weekly basis from February 2009- January 2010. Methodologically, descriptive analysis, cluster analysis, generalized estimating equations (GEE), trends of vegetables wholesale and consumer monthly prices, income distribution and benefit cost ratio (B/C) were employed in this study to characterize urban agriculture in Khartoum. The research methodology framework comprising interviewed stakeholders, data collection and analysis, is depicted in Figure 6.1.

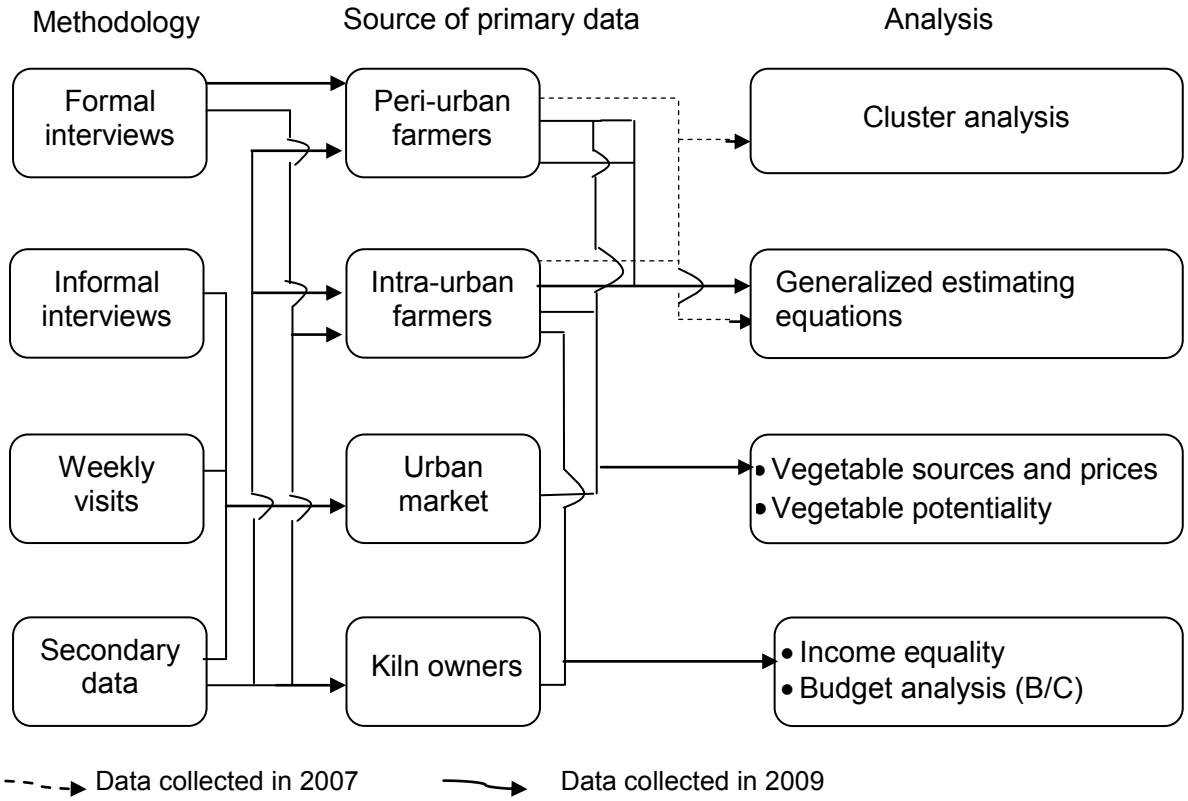

Figure 6.1. Schematic framework to show the interviewees, data collection, and analysis methods.

6.2. Main characteristics of UPA Khartoum, Sudan

6.2.1 Definition of UPA and classification of urban farmers in Khartoum

The question of how to portray UPA Khartoum was raised as Mougeout (2000) indicated the uniqueness of UPA in each city due to differences in elements and environment. Two locations were defined depending on the distance from city center. The agricultural areas near city center was defined as intra-urban while the agricultural farms relatively distantly located and in the peripheries, but still within the city boundaries, were defined as peri-urban. Cluster analysis was used to classify urban farmers and farming in Khartoum with due consideration to the different farmer groups where farmers were interviewed as: crop and mixed (crop and livestock) producers, private, cooperative members, or public schemes farmers. Key socioeconomic characteristics/variables of UPA farmers in Khartoum were incorporated in the cluster analysis using socioeconomic factors for farmer classification relevant to urban farming in Khartoum. This was based on classification undertaken in different studies of a set of respondents using socioeconomic characteristics such as that used to identify farmer groups more homogenous within and as heterogeneous as possible among tea and coffee smallholders in Murang'a district, Kenya (NYAGA, 2009), to that to distinguish between sheep keepers and non-keepers in Bobo-Dioulasso (SIEGMUND-SCHULTZE & RISCHKOWSKY, 2001), and that to illustrate plant biodiversity in Khartoum (THOMPSON ET AL., 2010). Farmers were classified upon production scale whereby the groups were defined as small, medium, and large farms. Analysis showed that intra-urban farms were small while those in the peri-urban setting accommodated all three farm sizes. In the small intra-urban farms, farmers benefit from being near to the market and resort to growing leafy vegetables intensively for their continuous income, as also confirmed by other studies (SCHUMACHER ET AL., 2009; THOMPSON ET AL., 2010). In peri-urban areas, having relatively larger farms, most of the farmers grow forage. Livestock owners cultivate forage crops to feed their animals because it is cheaper to do so than to buy forage from the market. Such indicated variability in UPA Khartoum is also evident in most of the studies for UA in Africa and countries in other regions (DIOGO, 2009; GRAEFE ET AL., 2008; THOMPSON ET AL., 2010). This variability in crops and animal products positively supports food production in Khartoum where the products are assumed to be perishable and preferred to be produced in the city zone.

6.2.2. Crop sales

Farmers resort to sale of their products, both leafy vegetables and forage, in the farm at harvest time and the buyers bear the harvesting cost. Sometimes when the farm price of the cultivated crop falls down before sale, especially for leafy vegetable, farmers plow the crop in the soil to avoid harvest cost; this behavior was mentioned by OLSON (2011).

6.2.3 Assets index

The asset index was used in some studies as welfare indicators for respondents (FEUELFACK ET AL., 2006; FILMER & PRITCHETT, 1998; SAHN & STIFEL, 2003). The resulting low level of asset index of urban farmers in Khartoum reflects slow accumulation of wealth among sampled farmers.

6.2.4. Why cluster analysis and classification

As case-driven cluster analysis may not capable of distinctive separation of UA farmer groups in Khartoum in view of the fact that different farmer groups were interviewed. In general, cluster analysis gives information about the variability and potential of moving from a certain group to another , especially for non-native farmers who can move from urban location to peri-urban farms in Khartoum or mixed producers to be crop producers and vice versa. This situation was described by SIEGMUND-SCHULTZE & RISCHKOWSKY (2001) when classifying the sheep keepers and non-keepers in Bobo-Dioulasso, Burkina Faso. This was referred to as “transition groups” due to their characteristics which means the ability of farmers to shift from one system to another. In the context of urban Khartoum, cluster analysis confirmed differentiation and high variability and potentiality. The different groups have different needs where extension and supportive services should consider these variations. Farmers needs guide the production activities and behaviour. This at the end serves the agricultural sector in the studied area. As an example, some farmers in peri-urban areas shift to forage production rather than food crops because of lower cost and relatively easy crop management. This increases the total area cultivated by forage at the expense of food crops area. Well understanding and consideration of farmer’s needs and potentials by service providers in the agricultural sector could improve the outcome of this sector.

6.2.5. Farmers’ priorities

Ranking of priorities of respondents showed that farmers were more inclined to food provision and are income seeking. Intra-urban farmers showed more agreement among them, with moderate (*W*), than farmers in peri-urban area with low (*W*). The low Kendall’s coefficient of concordance (*W*) showed that practitioners have different perspectives and priorities as stated by DOSSA ET AL. (2007). In practicing agricultural activities in the urban and peri-urban agriculture in Khartoum low *W* showed variation in farmers perspectives, which indicates differences in farmers needs and priorities. Investigating reasons for keeping goats in Southern Benin, DOSSA ET AL. (2007) got relatively high *W* for keeping two goat types indicating that the main reason was related to income earning. Also ANANG ET AL. (2011), investigating the constraints of Ghana’s cocoa sector reform, found that farmers got a relatively moderate *W*. The result of low *W* among farmers in Khartoum is on the same line with low asset index.

6.2.6. Further studies

The findings entail different plans for investigating the incentives and constraints faced by farmers groups differently and respond to their needs and priorities. Further studies are required

in this regard intentionally to improve urban agriculture in Khartoum, which at the end be as guidance for extension and other service providers to supply suitable information and services for each farmer group.

6.3. Changes in farm production means and farm cash income

Agricultural work is unstable because of changes either in climatic or socioeconomic factors of farmers such as adoption of new technologies and crops cultivated (EDMONDS, 1999; MAWOIS ET AL., 2011). This part aimed to identify the changes in different elements at the farm level where a survey was conducted in 2007 and again in 2009 among a randomly selected sample of urban farmers in Khartoum. Iteration is known in panel data where the cases in the study are decreasing from time to the next time. In this study it was difficult to cover the whole sample interviewed in 2007 for the second time in 2009. During the second survey almost all study sites were visited and farmers who were available and willing to cooperate were interviewed. Those who were not interviewed were either no more practicing agriculture, were not present on site, changed their farms, or were busy elsewhere. The second survey covered 50% of the whole sample and all farmer groups were represented. The panel data improve data reliability more than cross section data.

6.3.1. Production means and fertilizer prices and quantities

Results indicated the changeability of production means and inputs in the agricultural activity. The analysis of the two years 2007 and 2009 showed that the farm size stayed almost the same while crop intensification decreased, but not significantly. At the same time prices of fertilizers have changed which had an effect on the amounts consumed. For instance, urea price has increased significantly. The consumed amount of urea has decreased while the consumption of chicken manure increased, which can be explained by the input substitution as indicated by CASAVANT ET AL. (1999).

6.3.2. Animals owned and product price

Animals ownership (cows, goats, and sheep) have changed also where the number of owners increased but not significantly. The average stocking rate (measured in tropical livestock units (TLU)) has slightly decreased. Milk productivity in liter TLU^{-1} increased while the average milk sale liter $year^{-1}$ decreased but not significantly at the same time when milk price increased significantly by 50%. The observed decrease in milk sales could be explained by the decrease in TLU.

6.3.3. Farm cash income

The average farm cash income showed a slight increase. Sampled farmers mentioned three main sources of agricultural income: crop sales, milk sales, and live animals sales. The share of income derived from crops has decreased from 70% to 65%. The contribution of live animals sales and milk sales also changed where milk sales slightly decreased and sales of live

animals slightly increased. These changes in the composition of agricultural sources of income showed flexibility and that the sampled farmers tried to enhance income from the different sources to cover expenditures. Some farmers showed negative farm cash income either in one year or in both 2007 and 2009. Getting negative income is not strange under changeable inputs and outputs market prices and lack of storage facilities in Khartoum, which is confirmed by ELRASHEED & AWAD (2009) among potato producers in Khartoum.

6.3.4. Income mobility

Sampled farmers also were grouped using farm cash income in quartiles in 2007 and 2009. Quartiles were used in some studies to group respondents and explore their situation being moved from one income level to another (PHIMISTER ET AL., 2004). The movement of farmers within quartiles during 2007 and 2009 indicated the changeability of annual farm income from year to year. The stability in staying in the quartile or income level increased with the increase of income level. The higher income group showed high staying in their income level compared to the low income group. PHIMISTER ET AL. (2004) who indicated significant amount of farm income mobility and indicated that the staying ratio in the income level was higher for the higher and lower income levels than other in-between levels.

6.3.5. Effect of socioeconomic factors on income

The effect of socioeconomic factors was studied on both amount of farm cash income and probability of joining the higher income group using GEE, which considers correlation within individuals (HARDIN & HILBE, 2003; GHISLETTA & SPINI, 2004). ZEGER & LIANG (1986) pointed out to the importance of considering this correlation to obtain consistent parameters. The population-averaged (PA) analysis models the marginal outcome for population and not for individuals. The factors affecting farm cash income significantly in the study area as identified from our findings were education, farm size, chicken manure (ton ha^{-1}), percentage of forage area, and milk productivity. On the other hand the level of income, whether low or high, is affected by farm size, off-farm income, family size, location, and education. The possibility to stay in the low income group for many years depends on different factors as mentioned above. In the literature, with more than two years of Study length and data collection, PHIMISTER ET AL. (2004) and JARVIS & JERKINS (1998) indicated that the change in income at the next year is higher than the change after many years. Also both authors confirmed that the farm size and farmers age have significant effect on farm income.

The result of this part is generally giving information about income mobility and changes in the farm means in the urban areas. One of the limitation is that the study was conducted for two years where the longer study duration the more can be explored about the dynamics of agricultural work.

6.4. Khartoum vegetable market

Markets have great effects on farmers decisions with regard to which crops to be grown and when. Khartoum urban and peri urban agriculture covers approximately 12% of the total vegetable area in Sudan (Directorate of Agricultural Statistics, Federal Ministry of Agriculture, 2003).

6.4.1. Collection and sources of data

Two types of data were used in this chapter, primary data collected during weekly visits to Shambat central market and secondary data obtained from relevant sources (AJIMI ET AL., 2005; Central Bureaue Statistics; Directorate of Agricultural Statistics, Federal Ministry of Agriculture (2003), Directorate of Horticultural sector, Federal Ministry of Agriculture (2000-2004)). Different weekly price data was reported at different times of the day of collection as well as by different traders; therefore for each crop at least three traders were asked from the crop price and then the average was calculated. Vegetables prices in general showed variations and movement even within the same day. The secondary data were either collected using formal surveys or estimated using indicators from previous surveys conducted by the respective Directorate in the Ministry of Agriculture.

6.4.2. Harvest decisions

Price movements from day to day and month to month affect farmers decisions with regard farm income improvement where farmers respond to market price and cultivate crops of higher market price as confirmed by OLSON (2011). Because of sensitivity and lack of storage facilities, farmers lose their harvest and accordingly the expected income from vegetable crops (ELRASHEED & AWAD, 2009).

6.4.3. Financial issues

One of the main issues is the financial support provided by traders in the central market to vegetable producers either from Khartoum or from the other country region to fill the gap in crops when the market price is high.

6.4.4. Vegetable consumption

Vegetables consumption in Khartoum is very low, standing at 112 g capita^{-1} day^{-1} as found by FAO (2010) while international recommendation is 400 g capita^{-1} day^{-1} (WHO, 2003). The potential of vegetables production in Khartoum is high as indicated by statistics and also confirmed by findings of ELRASHEED & AWAD (2009). This indicates the potential for higher consumption and/or for exportation of vegetable crops. ELRASHEED & AWAD (2009) agreed that both high consumption and exportation will support producers financially.

6.4.5. Prices and sources of vegetable

As vegetable prices change (ELRASHEED & AWAD, 2009; EMAM, 2011) the Shambat central market gave evidence for prices showing movements up and down where each crop has his own unique monthly prices line. These price patterns reflect the seasonality factor where during production season price is low and during off-season price starts to increase to reach maximum

and then starts to decrease. Monthly wholesale prices significantly varied for most of the crops except for cowpea and purslane. Some crops are available during the whole year in the market, others are only available during their production season while others are available from time to time. In spite of the relevant high changes in tomato prices, EMAM (2011) indicated that returns to wholesalers is higher than that to retailers, which indicates that price changes are mostly for the benefit of wholesalers.

The change in price encourages producers from other regions where climate suits vegetable production during the off-season at Khartoum to bring their products there so as to get advantage of the higher prices compared to their areas. This was confirmed by wholesale traders when asked about the sources of vegetable crops in Shambat central market, Khartoum North. The traders mentioned many regions of Sudan as source for different crops. Some areas produce more than one crop and some crops come from different regions. This information is valid for almost all crops except for leafy vegetables, which are mainly grown in Khartoum intra- and peri-urban areas. EMAM (2011) indicated that Khartoum is the largest vegetable market in Sudan, which receives large amounts of vegetables from other country regions.

6.4.6. Consumer prices

The consumer nominal prices (NP) were obtained from the Central Bureau Statistics on monthly basis. NP was converted to real price (RP) using consumer price index (CPI). The real prices are expected to show the situation at the social level, allowing comparison over time with respect to price movements and their trends where the effect of inflation was removed. The analysis of annual real prices (ARP) compared to annual nominal prices (ANP) resulted in different price patterns. While the ANP showed significant variation for all tested crops, the ARP showed significant variation for most of them (except for tomato and onion). On the other hand, analysis of monthly nominal prices (MNP) gave significant variation for less number of crops in the test and this was the same for monthly real prices (MRP). The change in annual and monthly prices was confirmed by ELRASHEED & AWAD (2009) for potato in Khartoum and by EMAM (2011) for tomato.

6.5. Red brick making and agricultural activities

6.5.1. Land use in agriculture and red brick making activities

Land use is an important issue in intra-urban area where land is limited and different uses are competitors (HOOVER & GIARRATANI, 1999). Allocation of resources to get the maximum utility is approved by economists as the optimum behavior but because of limited resources and variation and expansion of people's needs this allocation varied from place to place and from community to community (CASAVANT ET AL., 1999). The competition among different land usages is depending on different factors. The location and main economic activity of land owners is among those factors (HOOVER & GIARRATANI, 1999). The intra-urban land

along the river bank is fertile and renewed yearly with silt during flooding season. The renewable clay along the banks of the River Nile and location near to the populated area and city market increased the land value for users as confirmed by HOOVER & GIARRATANI (1999). The mentioned characteristics make this land suitable for agricultural production as well as for red brick production (BM), as also reported for India (SINGH & SARFARAZ ASGHER, 2005). This suitability encourages the shift of land use from agriculture to red brick making (ALAM & STARR, 2009; SCHUMACHER ET AL., 2009). These circumstances are found also in different countries like Vietnam and Pakistan (ISHAQ ET AL., 2010; JENSEN & PEPPARD, 2004). The profitability of each activity (agriculture and red brick making) and the value of payment to land owners are considered as one of the incentives for bidding each other (HOOVER & GIARRATANI, 1999; LANKOSKI & OLLIKAINEN, 2008; MUTO, 2006; SAZAK, 2004). The other activities with higher value bidding reduces/removes agriculture in city center and moves it to the peri-urban and borders (HOOVER & GIARRATANI, 1999; MUTO, 2005; SINGH & SARFARAZ ASGHER, 2005).

6.5.2. Income distribution and Gini index

Red brick kilns owners have better income distribution than farmers in intra-urban areas. This indicate the relatively stable income and less risk in the BM activity compared to farming. Gini coefficient, as an income inequality measure, has some limitations. Those limitations are very much related to its nature such as ignoring details and sources of income. It is not telling an information about household welfare as it ignores the wealth and/or assets accumulated by the household. This measure is static; only giving information at the time of measurement and does not describe income distribution overtime (JENKINS & PHILIPPE, 2009). A further detailed study is needed to investigate the welfare of agrarian household, the use of income in agricultural activity, and the way for improvement of household income.

6.5.3. Benefit cost ratio

The B/C ratio is higher in the agricultural activity than in BM activity, which indicates the higher return to capital in agriculture than BM. Considering this and the mentioned disadvantages of BM kilns, this study recommends to shift back to agricultural production by addressing the constraints faced by agricultural production in the study area.

6.5.4. GHGs production

The firing process using wood and compacted manure produced GHGs that polluted air in the study area in spite of being small 10% of total Sudan GHGs. Beside the deforestation of 2 ha $year^{-1}$. The contribution of BM on environmental pollution was admitted for Sudan (ALAM & STARR, 2009) and Pakistan (ISHAG ET AL., 2010).

6.5.5. Animal manure uses

In Sudan the BM does not only use land but also use animal dung, loose and compacted, as an ingredient in mixture and for burning, which is determined as lose and sink for N, P and K nutrients and organic matter. In Sudan, animal dung is not commonly used as manure in agriculture but as biomass fuel in BM (ALAM & STARR, 2009; OMER & FADALLA, 2003), in spite of

confirmed research results on its benefits to crop yields and soil characteristics (ABDALLA ET AL., 2007; GAFFAR ET AL., 1992; SULIEMAN ET AL., 2009). Its importance was also reported for soil characteristics and nutritious value for agricultural crops in different countries, especially in urban farming (DIOGO ET AL., 2011; OGUNGBILE ET AL., 1998). This study confirmed that available nutrients in animal manure are slightly cheaper in comparison to chemical fertilizer. Further, the use of such wastes as a fertilizer will lead to decrease the imports of chemical fertilizers in addition to avoid the cost of their disposal. It was reported by other studies that in Kassala state in East Sudan, bagasse falling out of the sugar industry there is used as organic additive in bricks instead of animal wastes and as fuel fire making instead of wood. This substitution removes industrial wastes from farms and decreases the produced GHGs (ALAM, 2006; LOWE & SCHILDERMAN, 2001; PRACTICAL ACTION, 1999).

6.6. Conclusions and recommendations

Socioeconomic factors were addressed in this study for well understanding of UPA Khartoum, Sudan. The internal elements of UA and interactions with the external environment, such as other activities using the same resources, have effect on the performance of UA. Classification helps in identify the potentials and constraints of UA in addition to ease the role of development partners to enhance the performance of agricultural activities in the study area.

This study suggests some recommendations to improve the performance of farming in UA Khartoum:

1. Further investigations are needed to fine-tune opportunities in, and efficient use of, resources and inputs in UPA agriculture.
2. Identifying and address the constraints and limitations faced by small farmers in UPA Khartoum to develop this sector.
3. The cropping pattern within which vegetable and forages are cultivated needs more investigation to identify the opportunities to expand production of food crops.
4. A further detailed study is needed to explore the social welfare of agrarian households, interactions of farm and off-farm incomes and their allocation to support agricultural activities.
5. Enacting legislation and regulations to protect land and stabilize market prices of vegetables conducive to enhancing incomes of farmers and developing vegetable production in the study area.

6.7. References

ABDALLA, M. A., SALIH, N. O., HASSABO, A. A. and MAHALA, A. G. (2007): Effect of application of organic amendments on quality of forage sorghum (Sorghum bicolor L.) in the semi-arid tropics. Archives of Agronomy and Soil Sciences 53(5): 529-538.

AHMED, A. A., IBRAHIM, S. A. S., OGEMBO, O., BABIKIR, I. A. A. and FADUL, H. M. (2010): Nile River bank erosion and protection. The Nile Basin Capacity Building Network (NBCBN)-RE.

ALAM, S. A. (2006): Use of biomass fuels in the brick-making industries of Sudan: Implications for deforestation and greenhouse gas emission. Thesis submitted for an M. Sc. Degree in Forest Ecology, Tropical Silviculture, Department of Forest Ecology, Viikki Tropical Resources Institute (VITRI), University of Helsinki.

ALAM, S. A. and STARR, M. (2009): Deforestation and greenhouse gas emissions associated with fuelwood consumption of the brick making industry in Sudan. Science of the Total Environment 407: 847–852.

ANANG, B. T., ADEUSEI, K. and MINTAH, E. (2011): Farmers' assessment of benefits and constraints of Ghana's Cocoa sector reform. Current Research Journal of Social Sciences 3(4):358-363.

CASAVANT, K. L., INFANGER, C. L. and BRIDGES, D. E. (1999): Agricultural economics and management. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

CBS (CENTRAL BUREAU OF STATISTICS) (2009): Statistical year book for the year 2009" Ministry of the Cabinet, Government of the Republic of the Sudan, Khartoum.

DIOGO, R. V. C. (2009): Horizontal nutrient fluxes and production efficiencies in urban and peri-urban crop and livestock husbandry of Niamey, Niger. Dissertation presented to the Faculty of Organic Agricultural Sciences/ Group Animal Husbandry in the Tropics and Subtropics University of Kassel.

DIOGO, R. V.C., BUERKERT, A. and SCHLECHT E. (2011): Economic benefit to gardeners and retailers from cultivating and marketing vegetables in Niamey, Niger. Outlook on Agriculture 40(1): 71–78.

DOSSA, L. H., WOLLY, C. and GOULY, M. (2007): Smallholders' perceptions of goat farming in southern Benin and opportunities for improvement. Tropical Animal Health and Production 39: 49-57.

EDMONDS, C. M. (1999): The effect of technology transfer program participation on small farms in Chile. Selected paper for presentation at the Annual Meeting of the American Agricultural Economics Association, August 8-11, 1999, in Nashville, Tennessee.

ELRASHEED, M. M. M. and AWAD, F. H. B. (2009): Economics of potato production and marketing in Khartoum State. Journal of Science and Technology 10(2): 80-91.

EMAM, A. A. (2011): Evaluating marketing efficiency of tomato in Khartoum State, Sudan. Journal of Agriculture and Social Sciences 7: 21-24.

FAO (2010): Food consumption. Available at: http://www.fao.org/economic/ess/food-security-statistics/en/. Accessed 6.1.2011.

FEULEFACK, J. F., ZELLER, M. and SCHWARZE, S. (2006): Accuracy analysis of Participatory Wealth Ranking (PWR) in socio-economic poverty comparisons. Discussion paper No. 44.

Department of Agricultural Economics and Rural Development, Socioeconomics of Rural Development, University of Goettingen, ISSN 1433-2868.

FILMER, D. and PRITCHETT, L. (1998): Estimating wealth effects without expenditure data -- or tears: with an application to educational enrollments in states of India. Policy research working paper No. 1994, The World Bank.

GAFFAR, M. O., IBRAHIM, Y. M. and WAHAB D. A. A. (1992): Effect of farmyard manure and sand on the performance of Sorghum and sodicity of soils. Journal of Indian Society of Soil Science 40(3).

GHISLETTA, P. and SPINI, D. (2004): An introduction to generalized estimating equations and application to assess selectivity effects in a longitudinal study on very old individuals. Journal of Educational and Behavioral Statistics 29(4): 421-437.

GOCKOWSKI, J., MBAZO'O, J., MBAH, G. and MOULENDE, T. F. (2003): African traditional leafy vegetables and the urban and peri-urban poor. Food Policy 28: 221–235.

GRAEFE, S., SCHLECHT, E. and BUERKERT, A. (2008): Opportunities and challenges of urban and peri-urban agriculture in Niamey, Niger. Outlook on Agriculture 37(1): 47-56.

HARDIN, J. W and HILBE, J. M. (2003): Generalized estimating equations Champan & Hall/CRC.

HOOVER, E. M. and GIARRATANI, F. (1999): An introduction to regional economics. Third edition © 1999, Regional Research Institute, WVU.

ISHAQ, M., KHAN, M. A., JAN, F. A. and AHMAD, I. (2010): Heavy metals in brick kiln located area using atomic absorption spectrophotometer: a case study from the city of Peshawar, Pakistan. Environmental Monitoring and Assessment 166: 409–420.

JARVIS, S. and JERKINS, S. P. (1998): How much income mobility is there in Britain?. The Economic Journal 108: 428-443.

JENKINS, S. P. and PHILIPPE, K. V. (2009): The measurement of economic inequality. In: SAVERDA, W., NOLAN, B. and SMEEDING, T. M. (Eds.). (2009): The Oxford handbook of economic inequality. Oxford University Press.

JENSEN, R. and PEPPARD, D. M., Jr. (2004): The traditional brickmaking industry and the rural economy of Vietnam. Journal of Asian and African Studies 39(3): 193–207.

LANKOSKI, J. and OLLIKAINEN, M. (2008): Bioenergy crop production and climate policies: a von Thünen model and the case of reed canary grass in Finland. European Review of Agricultural Economics 35(4): 519-546.

LOWE, L. and SCHILDERMAN, T. (2001): Building in partnership: the story of Shambob. ITDG practical answers for poverty.

MAWOIS, M., AUBRY, C. and BAIL, M. L. (2011): Can farmers extend their cultivation areas in urban agriculture? A contribution from agronomic analysis of market gardening systems around Mahajanga (Madagascar). Land Use Policy 28: 434–445.

MOUGEOT, L. J. A. (2000): Urban Agriculture: definition, presence, potentials and risks, and policy challenges. In: BAKKER, N., DUBBELING, M., GUENDEL, S., SABEL KOSCHELLA, U. and DE

ZEEUW, H. (Eds.): Growing cities, growing food, urban agriculture on the policy agenda. DSE, Feldafing, pp 1-42.

MUTO, S. (2006): Estimation of the bid rent function with the usage decision model. Journal of Urban Economics 60: 33-49.

NYAGA, E. K. (2009): A socioeconomic analysis of resources and living standards of tea and coffee smallhoders in Murang' a district, Kenya. In: DOPPLER, W., MAJDALAWI, M., and ALMOHAMED, S. (Eds.): Economics resources use and farming systems development in the Middle East and East Africa. Margraf Publishers Gmbh, 2009.

OGUNGBILE, A.O., TABO, R., VAN DUIVENDOODEN, N. and DEBRAH, S. K. (1998): Analysis of constraints to agricultural production in the Sudan Savanna zone of Nigeria using multi-scale characterization. NJAS Wageningen Journal of Life Sciences 46(1): 1–8.

OLSON, K. D. (2004): Farm management principles and strategies. Iowa state press, A Blackwell Publishing Company.

OLSON, K. D. (2011): Economics of farm management in a global setting. John Willey and Sons, Inc.

OMER, A. M. and FADALLA, Y. (2003): Biogas energy technology in Sudan. Renewable Energy 28: 499–507.

PHIMISTER, E., ROBERTS, D. and GILBERT, A. (2004): The Dynamics of Farm Incomes: Panel data analysis using the Farm Accounts Survey. Journal of Agricultural Economics 55(2): 197-220.

PRACTICAL ACTION (1999): Utilization of bagasse in Brickmaking R&D in Sudan. Practical Action, the Schumacher Centre for Technology and Development.

SAHN, D. E. and STIFEL, D. C. (2003): Urban-Rural Inequality in Living Standards in Africa. Journal of African Economies 12(4): 564-597.

SAZAK, S. (2004): The role of landowners in the transformation of land affected by the metropolitan city, “Corlu”. Land Use Policy 21: 21-31.

SCHUMACHER, J., LUEDELING, E., GEBAUER, J., SAIED, A., EL-SIDDIG, K. and BUERKERT, A. (2009): Spatial expansion and water requirements of urban agriculture in Khartoum, Sudan. Journal of Arid Environments 73: 399–406.

SIEGMUND-SCHULTZE, M. and RISCHKOWSKY, B. (2001): Relating household characteristics to urban sheep keeping in West Africa. Agricultural Systems 67: 139-15.

SINGH, A. L. and SARFARAZ ASGHER, M. (2005): Impact of brick kilns on land use/landcover changes around Aligarh city, India. Habitat International 29: 591–602.

SULIEMAN, S. A., ABDALLA, M. A., OMER, E. A. and HAGO, T. E. M. (2009): Phosphorous supply and *Phaseolus vulgaris* performance grown in Shambat clay-alkaline soil and influence by farmyard manure. Australian Journal of basic and Applied Sciences 3(3): 2598-2606.

THOMPSON, J. L., GEBAUER, J., HAMMER, K. and BUERKERT, A. (2010): The structure of urban and peri-urban gardens in Khartoum, Sudan. Genetic Resources Crop Evolution 57: 487– 500.

WHO (2003): Diet, nutrition and the prevention of chronic diseases. WHO technical report series, 916, Report of a Joint WHO/FAO Expert Consultation Geneva.

ZEGER, S. L. and LIANG, K. (1986): Longitudinal data analysis for discrete and continuous outcomes. Biometrics 42: 121-130.

Urban agriculture (UA) is associated with the production of fresh vegetables and milk by native and non-native farmers and households. It enhances consumption of healthy food and improves the livelihood of urban practitioners. This study investigates the main internal elements and external environments of UA in Khartoum, the capital of Sudan. Urban farmers are classified using a set of socioeconomic factors that affect farm income and describe the levels of farm income. Due to the fact that market access is one of the main factors of success, market channels are pictured. In addition, prices and price changes over time as well as the market characteristics from the wholesalers' and farmers' point of view are investigated. Changes in land use and upcoming land competition between agriculture and red brick production along the River Nile will affect the future economics and ecology of urban and peri-urban agriculture systems.

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